Pervasive Technology Institute Annual Report: Research Innovations and Advanced Cyberinfrastructure Services in Support of IU Strategic Goals During FY 2015

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PERVASIVE TECHNOLOGY INSTITUTE
INDIANA UNIVERSITY

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1. Executive Summary

A hundred years ago, science was either empirical (occupied with the task of describing natural phenomena) or theoretical (based on mathematical models). Today, it takes two additional forms:

- Computational science that uses computers to simulate complex problems
- Data exploration science that generates new knowledge using data captured by measurement systems, processed with software, and archived for long-term storage

Both forms of science require substantial underlying software tools and computers. Today's use of technology is pervasive throughout science, engineering, clinical and translational research, and the arts.

In 1999, under the leadership of Michael A. McRobbie (then vice president of information technology), Indiana University proposed a partnership with Lilly Endowment to fund key elements of the launch of the School of Informatics and Computing and the creation of six advanced information technology labs that became known as the Pervasive Technology Labs (PTL).

The core rationale had three main components: Indiana's economy was lagging behind many other states and in fact leading the nation in several negative economic indicators; state leadership had established a strategy of restoring the Indiana economy on the basis of life sciences and information technology; and, with funding to build on and expand existing strengths in computer science and information technology, IU could contribute strongly to economic as well as scientific and societal good in Indiana.

In 2008, IU proposed the transformation of the Pervasive Technology Labs into the Pervasive Technology Institute, enabled by a second round of funding from the Lilly Endowment and increased IU support. Now, as we end fiscal year 2015, the IU Pervasive Technology Institute (PTI) completes 16 years of innovation and service to Indiana University, the state of Indiana, and the United States generally.

As of the end of June 2015, PTI has completed its first year of sustainability without any funding from the Lilly Endowment, continuing and refining its activities within IU, the state of Indiana, and the nation. Some of the key accomplishments are:

- **Jetstream.** The NSF awarded $6.7M to PTI to lead the creation of Jetstream, a first of a kind interactive cloud computing resource to support science and engineering research.
- **Science Gateway Group provides science-enabling platform as a service and open source software.** SGG group manager Marlon Pierce serves as PI of the NSF-funded Science Gateway Platform as a service (SciGaP.org) project, which provides scalable, hosted services for science gateways developed by collaborators across the country.
- **Advanced Visualization Lab improves the IQ series.** The IQ series represents the core of AVL's distributed visualization initiative, which uses commercial-off-the-shelf hardware and open-source software to provide low-cost, advanced visualization resources for the university community and beyond.
- **Programmable Immersive Peripheral Environment Systems (PIPES).** (Programmable Immersive Peripheral Environment System) is a tool that extends commonly used virtual reality systems in support cyber-physical applications.
- **Research into Return on Investment in supercomputing and advanced cyberinfrastructure.** PTI Executive Director Craig Stewart and a team of XSEDE researchers analyzed the costs and benefits of federal investment in XSEDE – the eXtreme Science and Engineering Discovery Environment – and determined that the ROI on federal investment is indeed greater than one.

2. Introduction

The Indiana University Pervasive Technology Institute's goals are to:

- Cultivate and enable creativity and innovation in science and scholarship by developing new innovations in cyberinfrastructure, informatics, and computer science
- Create association and collaboration capabilities for researchers at IU (and beyond) to:
    - Be the partner of choice within IU and the nation for creating and implementing cyberinfrastructure facilities (particularly when funded by a grant or contract focused on construction of a new facility or delivery of a new capability)
    - Enable the translation of software innovations to practical use
- Impact the economic health and quality of life in Indiana, creating new jobs and nurturing new businesses
- Support the development of a 21st century workforce within the state of Indiana
- Offer services that enable new innovations and accelerate research by the IU scientific, scholarly, clinical, engineering, and artistic communities

PTI is an inherently collaborative organization. Reporting organizationally within the Office of the Vice President for Information Technology (OVPIT), PTI is an institute created by collaborations across OVPIT, University Information Technology Services (UITS), the Maurer School of Law, and the College. PTI is organized into two types of functional units: research centers and service centers. The goal of this structure is to assure that collaboration, which has become a defining characteristic of PTI, crosses organizational boundaries, so practice can inform science and science can advance practice. PTI's research centers operate like any traditional research group. Their mission is to innovate within the scope of IU's mission – experimenting, trying new ideas, hitting dead ends, and creating new possibilities in informatics, computer science, the natural and social sciences, the humanities, the fine and performing arts, medical and clinical research, and engineering. The PTI research centers are:

- Center for Applied Cybersecurity Research (CACR), led by Von Welch
- Data to Insight Center, led by Professor of Informatics Dr. Beth Plale, also PTI Science Director
- Digital Science Center, led by Distinguished Professor of Computer Science Dr. Geoffrey C. Fox

The PTI Cyberinfrastructure[1] and Service centers are:

- Research Technologies Division of UITS, led by Associate Dean Dr. Craig A. Stewart, also Executive Director of PTI and adjunct associate professor of computer science in the IU School of Informatics and Computing
- The National Center for Genome Analysis Support, led by Dr. Thomas G. Doak

PTI operates within and supports Indiana University's vision (strategicplan.iu.edu):

> *To be one of the great research universities of the twenty-first century and to be the preeminent institution of higher education in Indiana, specifically by:*
>
> *1. Providing an excellent, relevant and responsive education across a wide range of disciplines in baccalaureate, graduate, and professional education to students from all backgrounds from Indiana and around the globe;*
>
> *2. Pursuing excellent world-class research, scholarship, and creative activity; and*

[1] Cyberinfrastructure "consists of computing systems, data storage systems, advanced instruments and data repositories, visualization environments, and people, all linked by high speed networks to make possible scholarly innovation and discoveries and new artistic expressions not otherwise possible" as defined in Stewart et al. 2014 https://scholarworks.iu.edu/dspace/handle/2022/18608.

3. Engaging in the economic, social, civic, and cultural development of Indiana, the nation, and the world by building on the base of excellence in research and education.

In the following report, PTI activities are described according to the five major goals outlined above, with references to how these activities relate to contributions toward the Bicentennial Strategic Plan for Indiana University[2] and the Principles of Excellence[3]. The Bicentennial Strategic Plan for Indiana University (referred to as "IU Bicentennial Plan" hereafter) includes eight Bicentennial Priorities along with a number of continuing priorities related to the Principles of Excellence. In order to make it easy to identify contributions to Bicentennial Priorities and Principles of Excellence, information specifically related to these university-level goals is presented under 3rd-level headers within the table of contents. (PTI goals and sub-goals are 1st and 2nd level headings.) Appendix 1 on page **Error! Bookmark not defined.** provides a summary of PTI contributions to the metrics identified in the IU Bicentennial Plan, with two exceptions. First is Bicentennial Priority Four, which is specifically a priority for and internal to the School of Education. In addition, several programs are delivered and managed by PTI Research Centers that are subunits of the IU School of Informatics and Computing. To avoid any chance of double counting, this report does not include metrics on student activities related to activities bearing university course credits or resulting in awarding of degrees. These are reported as part of SOIC overall activities.

PTI engages in many research activities, and the PTI cyberinfrastructure and service centers offer a variety of services. Rather than include extensive text descriptions of these services within the text, Appendix 2 provides brief summaries.

This report will serve as a template for future PTI reports until IU declares a set of strategic priorities that function as successors to the IU Bicentennial Priorities document. This document serves as a successor that unifies information presented last year in 1) the final report on PTI activities submitted to the Lilly Endowment, 2) a report on cyberinfrastructure (CI), and 3) a separate report on CI services offered to the IU, state, and national communities by the two Cyberinfrastructure and Service Centers of PTI – the Research Technologies Division of UITS and the National Center for Genome Analysis Support[4].

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[2] Indiana University. 2014. The bicentennial strategic plan for Indiana University. https://strategicplan.iu.edu/doc/plan.pdf

[3] Indiana University. 2010. Principles of Excellence. http://president.iu.edu/img/containers/publications/Principles-of-Excellence_print-on-demand.pdf

[4] Stewart, C.A.; W.K. Barnett, , M.J. Boyles, B. Fulton, D.Y. Hancock, M.R. Link, T. Miller, S.A. Michael, M. Pierce, R.J. Ping, T. Miller, E.A. Wernert. 2015. Indiana University's advanced cyberinfrastructure in service of IU strategic goals: Activities of the Research Technologies Division of UITS and National Center for Genome Analysis Support - Two Pervasive Technology Institute cyberinfrastructure and service centers - during FY2014. Indiana University. http://hdl.handle.net/2022/19805

3. PTI Goal: Cultivate and enable creativity and innovation in science and scholarship by developing new innovations in cyberinfrastructure, informatics, and computer science

PTI overall and particularly the PTI Research Centers, which operate as small and nimble R&D centers, lead PTI in development of new innovations – and are the primary elements of PTI developing new innovations in cyberinfrastructure (CI), informatics, and computer science. Metrics describing research and innovation achievements during FY 2015 are summarized in Table 1 and then described in more detail for each center below.

Table 1. Research and innovation productivity metrics for PTI from inception of PTL in 1999

	Publications	Technical Presentations	Nobel Prize Awards Supported	Open Source Software Released
PTL & IUPUI 1999-2014	1,796	1,426 (data from 2008 forward)	3	178
PTI FY 2015	39	15	0	10
Totals	**1,835**	**1,441**	**3**	**A total of 10 current open source products are released by PTI**

3.1. Center for Applied Cybersecurity Research (CACR)

The Center for Applied Cybersecurity Research was established by Indiana University in 2003 to provide the nation with leadership in applied cybersecurity technology, education, and policy guidance. Fundamental to CACR's mission is to properly balance public needs, homeland security concerns, and individual privacy rights. The center has been named an NSA and DHS National Center of Academic Excellence in both Information Assurance Education and Information Assurance Research. CACR's accomplishments can be found in its 2015 annual report (https://scholarworks.iu.edu/dspace/handle/2022/20412). Highlights include:

- **CACR secures software through SWAMP.** CACR and the High Throughput Computing Group continue to provide the Software Assurance Marketplace (SWAMP), a $20 million DHS-funded facility that helps software developers and users more easily identify and fix security vulnerabilities in their software, reducing the risks with using that software. For more, see research highlight in section 4.1.2.2.
- **CACR director appointed as research advisor to InCommon Steering Committee.** Identity and authentication are critical foundations to cybersecurity. In the higher education community, InCommon, operated by Internet2, provides a secure and privacy-preserving identity federation for research and higher education. CACR Director Von Welch was appointed to the InCommon

Steering Committee as an advisor representing the research community, a newly created position recognizing Welch's leadership in securing our national research by leveraging federated identity.

- **IU designation as NSA/DHS National Center of Academic Excellence renewed.** The National Security Agency and the Department of Homeland Security renewed its designation of Indiana University as a National Center of Academic Excellence in Cyber Defense Research (CAE-R) and as a National Center of Academic Excellence in Information Assurance Education (CAE-E) through 2021. IU is one of just a handful of universities to have dual designations spanning more than one campus. IU's CACR coordinated the application process, working closely with faculty and staff at the IU School of Informatics and Computing, both at IU Bloomington and IUPUI.
- **CACR enables secure, large-scale DOE scientific collaborations.** Large-scale scientific collaborations now often span thousands of researchers across hundreds of sites around the globe. Supporting this scale creates tensions with traditional paradigms of data center operations, particularly with identity management. Under funding from the Department of Energy, CACR studied the last 15+ years of collaborative DOE science to construct guidance for supporting this large-scale science in a secure manner that coheres with risk management practices.
- **CACR assists with applied math project on medical device cryptography**. CACR worked with Professor Kevin Pilgrim in the department of Mathematics at IU Bloomington, on a research project with his undergraduate students. As part of a Mathematical Association of America (MAA) grant, he developed a course, "Case Studies in Applied Mathematics". One case study was a cryptography project that involved secure, wireless communication for a portable medical device. CACR's staff met with Professor Pilgrim and four students on multiple occasions and provided background information related to encryption and authentication. The students were later invited to present their project at the MAA PIC Math workshop (http://www.maa.org/programs/faculty-and- departments/pic-math).
- **CACR sponsors and organizes in support of the cybersecurity community.** During FY2015, CACR actively took strides to aide in the advancement of cybersecurity: sponsoring two SOIC students to attend the 2015 ACM Richard Tapia Conference; acting as an organizer of the January 2015 DOE/ASCR cybersecurity workshop[5]; organizing the Maurer Faculty Conversation on multi-disciplinary research as preparation for a DOD Minerva Initiative pre-proposal; sponsoring the 2015 Circle City Con; and funding a team from the Maurer School of Law and the School of Public and Environmental Affairs to compete in Georgetown Law's National Security Crisis Law Invitational Simulation[6].

[5] http://www.orau.gov/cybersecurity2015/

[6] https://itnews.iu.edu/articles/2015/iu-students-take-part-in-national-security-crisis-law-invitational-simulation.php

Highlight: CACR leads efforts for trustworthy scientific cyberinfrastructure

In an ideal world, NSF funded projects would be able to focus almost entirely on their research endeavors. However, the cybersecurity of NSF science and engineering projects can't be ignored. Even routine software needs safeguards against attackers looking to breach weak security protocols and take advantage of vulnerabilities.

Enter the Center for Trustworthy Scientific Cyberinfrastructure (trustedci.org). CTSC is comprised of cybersecurity experts who have an established track record of usable, high-quality solutions suited to the needs of science and engineering communities. CTSC targets three areas: one-on-one engagements with NSF projects to address specific challenges; education, outreach, and training to enhance cybersecurity across the scientific enterprise; and leadership to advance understanding of how cybersecurity leads to trustworthy science products.

The annual NSF Cybersecurity Summit, hosted by CTSC, brings together the NSF and research communities to increase understanding of the information assets that enable science. It also provides a community forum for professional development, networking, and best practices.

Led by the Center for Applied Cybersecurity Research, CTSC draws on expertise from multiple institutions, including Indiana University, the University of Illinois, the University of Wisconsin-Madison, the University of Wisconsin-Milwaukee, and the Pittsburgh Supercomputing Center.

To reinforce software protections, PTI's Center for Applied Cybersecurity Research (CACR) and High Throughput Computing group (HTC) have also joined forces. In 2014, the two began developing the Software Assurance Marketplace (SWAMP), supported by a $23.4 million grant from the Department of Homeland Security's Science and Technology Directorate.

The SWAMP (continuousassurance.org) serves as an open resource for software developers, software assurance tool developers, and software researchers looking to collaborate and improve software assurance activities in a safe, secure environment. Further, developers, educators, and IT professionals can use the SWAMP to perform free vulnerability assessments.

Along with teams from Morgridge Institute for Research (lead), University of Illinois at Urbana–Champaign, and University of Wisconsin–Madison, CACR and HTC work together to provide cybersecurity, monitoring, and user support for the SWAMP.

3.2. Data to Insight Center

The Data to Insight Center (D2I) is a research center at Indiana University. Its current projects are in data management, big data, data and text analytics, advanced cyberinfrastructure, tools for automated metadata and provenance capture, and the management and preservation of scientific data. D2I is proud to be part of PTI, where it leverages Indiana University's strengths in its Libraries and research cyberinfrastructure.

- Komadu is a standalone tool that can be added to an existing cyberinfrastructure for the purpose of collecting and visualizing provenance data. See the research highlight below for details.
- Komadu provides a Web Services API and a Messaging API for both provenance collection and querying collected data. Provenance collection is driven by notifications that represent a

particular event related to some activity, entity, or agent. Query API is mainly used to find details about a particular activity, entity, or agent and to generate a related provenance graph.

- Hathi Trust Research Center benefits from D2I cyberinfrastructure innovations that deliver optimal access and use of the HathiTrust corpus. The sheer size of the corpus demands innovative thinking about architecture and optimization at all levels of the software infrastructure from hardware to applications. D2I's research in this area focuses on reduced reads, intelligent caching, delivering maximum cycles at minimal costs, and providing secured environments for copyrighted materials. HTRC deals with 4.6 billion pages of printed material – so computational effectiveness and efficiency are critically important.
- The Sustainable Environment Actionable Data (SEAD) project, part of NSF's DataNet program, develops tools and services for active curation and long-term preservation of scientific data in sustainability science. It also provides a public interface to visualize and analyze the SEAD research network. D2I Director Plale is Co-PI of the SEAD project, and D2I plays a strong role in the development of C3P-R (Curate, Prepare, Package, and Publish Research) services that provide robust, scalable, and flexible solutions for the curation and publishing of research objects.

Highlight: Komadu offers new tool for managing and tracking data provenance

As researchers deal with ever-expanding data sets – and share them with colleagues around the world – it's increasingly important for that data to have a documented history, proving its validity and quality. Called "data provenance," this history reveals the origins of each data object and processes applied by various research teams. Good data provenance can have a transformational impact on scientific discovery.

In August 2015, the IU Data to Insight Center (D2I) released a new Komadu suite of software tools designed to help researchers track and verify digital data, a crucial step in computational research.

"The Komadu tools are made for capturing, representing, and using data provenance, which tells us where a piece of digital data came from, particularly digital data that has undergone transformation by software algorithms," said Beth Plale, director of D2I and managing director of PTI. "Who carried out a transformation on a piece of data, why, and when are all critical bits of information to someone interested in using the data in a different setting. Data provenance, for instance, can expose errors that crop up when one day's run of an image processing pipeline differs from another day because of a missing file."

D2I has been leading the data provenance charge for nearly a decade. In 2005, D2I researchers published one of the first papers on provenance, which helped to define the field. Shortly after, D2I researchers developed the Karma data provenance tool. Karma's experimental uses included studying the provenance of Global Environment for Network Innovations (GENI) data and ice sheet data captured by a NASA polar-orbiting satellite.

"Komadu is the most recent product to emerge from the Data to Insight Center's translational research trust," said Plale. "These tools are a tangible outcome of Lilly's investment in Indiana University, and one that my colleagues and I are certain will have a huge impact on big data research in a range of fields – bettering the lives of people around the world."

Komadu is just one of many tools being developed as part of the IU School of Informatics and Computing program in data science.

3.3. Digital Science Center

The Digital Science Center (DSC) focuses on creating an intuitive cyberinfrastructure with tremendous capabilities for supporting collaboration and computation. Easy-to-use, human-centered interfaces to cyberinfrastructure created by DSC will enable thousands of researchers in the public and private sectors to take advantage of cyberinfrastructure and accelerate innovation and discovery.

- The DSC received a major grant award from the National Science Foundation for a new software project called MIDAS (Middleware for Data-Intensive Analytics and Science). DSC director and distinguished professor Geoffrey Fox is leading the effort. See highlight below.
- Fox and DSC are playing a major role in the $12M NSF-funded Comet supercomputer, the world's first virtualized high performance computing cluster. Comet will be led by the San Diego Supercomputing Center, with IU and the SOIC Digital Science Center as key partners. IU Distinguished Professor Geoffrey Fox, PI of the NSF FutureGrid project and an expert in the use of virtual systems in supercomputing, is leading key elements of the virtualization technology used in Comet.
- Geoffrey Fox is also leading a $900,000 NSF-funded grant project to develop a Rapid Python Deep Learning Infrastructure, an artificial intelligence approach to solving big data problems.

Innovative research demonstrates value of NSF-funded eXtreme Science and Engineering Discovery Environment (XSEDE)

Are nationally funded cyberinfrastructure support services such as XSEDE valuable? Do they aid scientists? DSC's Gregor von Laszieski compared the publication impact of papers produced by scientists using XSEDE and NCAR resources.

This analysis introduces a percentile ranking-based approach of citations of the XSEDE and NCAR papers, compared to peer publications in the same journal that do not use these resources. This analysis is unique in that it evaluates the impact of the two facilities by comparing their reported publications to those of their peers from within the same journal issue.

Von Laszieski showed that, statistically, papers that feature XSEDE and NCAR resources are cited significantly more often than papers in the same journals that did not use these resources. This indicates that XSEDE and NCAR resources exert a strong positive impact on scientific research.

Highlight: MIDAS turns big data to gold

Led by IU Distinguished Professor of Computer Science and Informatics Geoffrey Fox, the MIDAS project addresses a leading challenge for some of the world's most pressing research: the ability to analyze and compute large amounts of data. Scientists are currently hampered by the ever-increasing volume, variety, and velocity of data. In response, MIDAS will develop and implement building blocks that enable key improvements in supporting data-intensive analysis on a range of cyberinfrastructure.

"Many scientific problems depend on the ability to analyze and compute large amounts of data, but this analysis often does not scale well," Fox said. "Our project will integrate features of traditional high-performance computing, such as scientific libraries, and communication and resource management middleware, with a rich set of capabilities already found in the commercial big data ecosystem."

Big data analytics are all about connections and relationships, as shown in this graphical representation

The five-year project will address major data challenges in seven research communities: biomolecular simulations, network and computational social science, epidemiology, computer vision, spatial geographical information systems, remote sensing for polar science, and pathology informatics.

"The project libraries created with this funding will have the same beneficial impact on data analytics that other scientific libraries have had for supercomputer simulations," Fox said. "And they will be implemented to be scalable and interoperable across a range of computing systems including clouds, clusters and supercomputers."

The team will engage other scientists and educators with annual workshops and activities at discipline-specific meetings, both to gather requirements for and feedback on the new software. The grant will also facilitate student outreach, and allow Minority Serving Institution students like those at Elizabeth City University in North Carolina to participate in new summer research experiences.

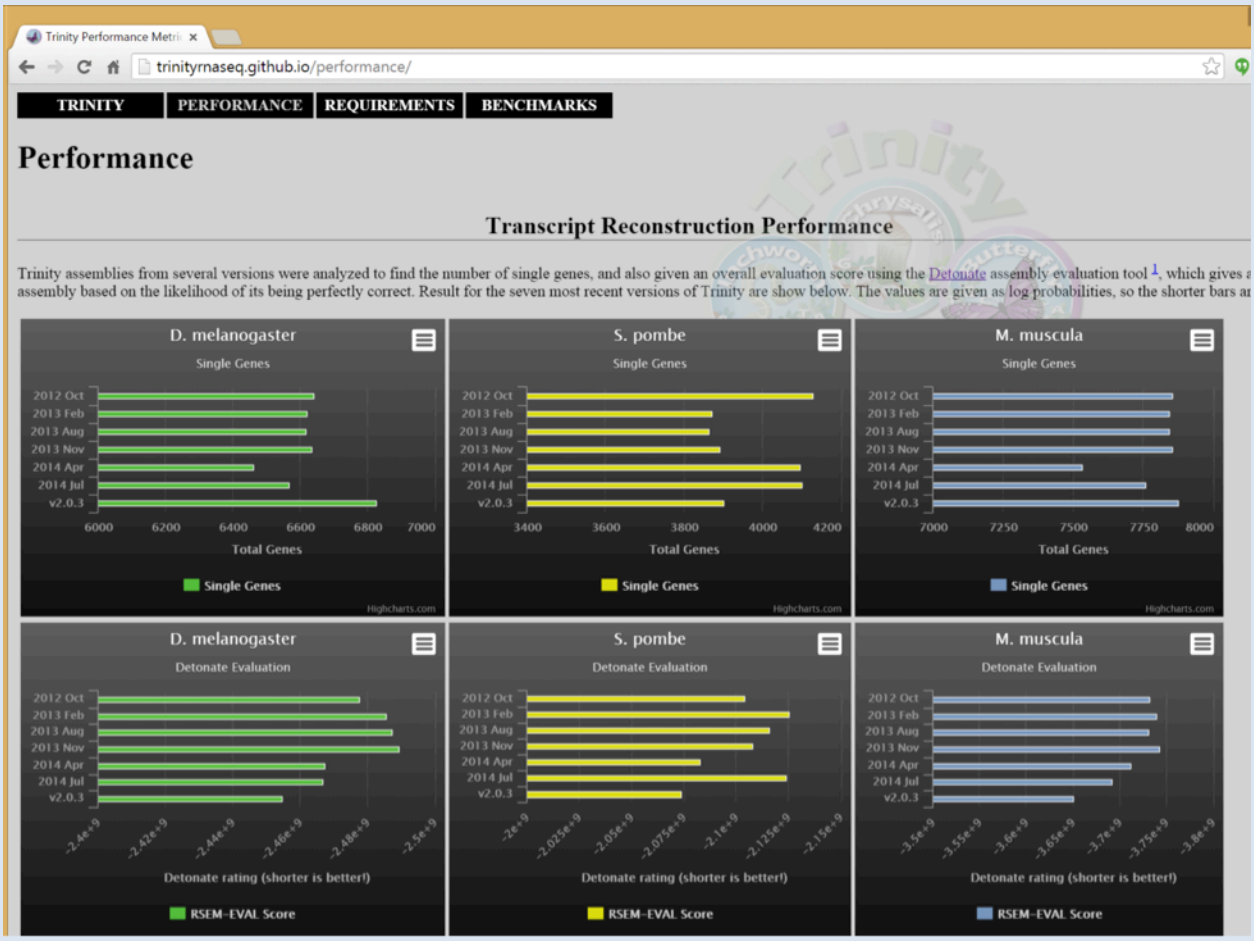
Judy Qiu and David Crandall, both assistant professors in the IU Bloomington School of Informatics and Computing, will serve as co-investigators working with Fox out of IU's Digital Science Center. Supporting researchers from the University of Arizona, Emory University, University of Kansas, Rutgers University, Virginia Tech, and the University of Utah will collaborate with the IU team.

3.4. National Center for Genome Analysis Support (NCGAS)

- **Expanded NCGAS services impact IUPUI researchers.** In April 2015, the IU-based National Center for Genome Analysis Support (NCGAS) announced new services and partnerships to further support genome science and researchers working to study the diversity of life, cure disease, and improve farming around the world.
- **NCGAS receives NSF renewal award.** The NSF Advances in Biologic Informatics (ABI) program has awarded NCGAS a three-year renewal to continue supporting genomics researchers, who do NSF-funded research or research compatible with NSF funding, nationwide. At the same time, leadership has transitioned: Thomas Doak is now NCGAS manager and primary PI on the renewal award, under the direction of Therese Miller.
- **NCGAS supports cancer bioinformatics via the Trinity project.** NCGAS continues to both improve and make widely available the Trinity suite of tools. Developed at the Broad Institute and Hebrew University of Jerusalem, Trinity is used to analyze gene expression – especially for cancer research – and is funded by the NIH National Cancer Institute's Information Technologies in Cancer Research program. For more on Trinity, see research highlight in section 3.5.
- **NCGAS provides an international GenePattern server.** GenePattern, a collaboration between researchers at the Broad Institute and UCSC, provides hundreds of analytical tools for gene expression, sequence variation and copy number, proteomic, flow cytometry, and network—all directed at the cancer research community. GenePattern is also funded by the NIH National Cancer Institute's Information Technologies in Cancer Research program. NCGAS and IU provide the service's primary server, running on PTI's Karst computer cluster.

Highlight: Improved Transcriptome Reconstruction with HPC and Trinity

Trinity, a sequence assembly application, reconstructs RNA transcripts from reads produced by next-generation sequencing platforms like Illumina. Following the latest release in January, IU developers analyzed reads from a variety of organisms to find opportunities for parallelization and other improvements. As a result of these performance and quality assessments, they were able to reduce the time required to assemble 50M reads from 19 hours to slightly more than 5.



Transcript Reconstruction Performance - Trinity assemblies from several versions were analyzed to find the number of single genes, and also given an overall evaluation score using the Detonate assembly evaluation tool, which gives a rating to the assembly based on the likelihood of its being perfectly correct. Result for the seven most recent versions of Trinity are show below. The values are given as log probabilities, so the shorter bars are the best scores.

IU performance tuning specialists are working with the Broad Institute and the Technische Universitat Dresden High Performance Computing center to analyze and improve the performance of Trinity using an array of profilers and methodologies. To assure high quality assemblies over a wide range of species, analyses have been performed for a vertebrate (house mouse), an invertebrate (fruit fly), and a yeast (brewer's fission yeast).

3.5. Research Technologies

The mission of the Research Technologies division of UITS is to develop, deliver, and support advanced technology solutions that enable new possibilities in research, scholarly endeavors, and creative activity at Indiana University and beyond – and to complement this with education and technology translation activities to improve the quality of life of people in Indiana, the nation, and the world. As such, it is more of an engineering, delivery, and service organization than it is an innovation organization. However, pursuing excellent service for the IU community often involves innovating. A few key innovative projects led by Research Technologies during FY 2015 are described below.

- **Jetstream.** The current National Science Foundation (NSF) cyberinfrastructure successfully serves thousands of researchers who are advancing critical areas of science and engineering. However, tens of thousands of other NSF-supported researchers are not using NSF-funded cyberinfrastructure (CI). In many cases these are researchers who do not fit the traditional high performance computing (HPC) or high-throughput computing (HTC) model for which existing NSF- and DOE- (Department of Energy) funded resources are optimized. The NSF-funded XD (eXtreme Digital) ecosystem—that is, the Extreme Science and Engineering Discovery Environment (XSEDE), and the service provider resources supported in part by XSEDE—has traditionally focused on HPC, recently adding more focus on HTC resources.

  Recognizing the need for more diversity in resources included in the XD ecosystem, NSF funded the Jetstream system with a grant award announced in November of 2014. Jetstream is NSF's first cloud computing system for use by all disciplines supported by the XD ecosystem. Jetstream is intended to be far reaching in scope, focusing on interactive delivery of resources from a "production-quality" cloud resource. Jetstream is led by the Indiana University Pervasive Technology Institute (PTI) with a large group of institutional collaborators involved in the construction of this resource: University of Texas at Austin's Texas Advanced Computing Center (TACC); University of Chicago; University of Arizona; and Johns Hopkins University. During the operations and management phase slated to begin when Jetstream goes into production use in January 2016, the list of partners and collaborators will expand to include the University of Texas at San Antonio. Other collaborators include Pennsylvania State University, Cornell University, University of Arkansas at Pine Bluff, University of Hawaii, the National Snow and Ice Data Center, the Odum Institute at the University of North Carolina, and the National Center for Genome Analysis Support (NCGAS). In this report, we describe the planned characteristics and functionality that will be enabled by Jetstream.

  Jetstream will be a configurable large-scale cloud computing resource that leverages both on-demand and persistent virtual machine technology to support a much wider array of software environments and services than current NSF resources can accommodate. As a fully configurable cloud resource, Jetstream bridges the obvious major gap in the current XD ecosystem, which has machines targeted at large-scale, high performance computing, high-memory, large-data, high-throughput, and visualization resources. Jetstream will offer a fundamentally new approach to computational service delivery for the national science community within the XD ecosystem, and will greatly increase the number of NSF-supported researchers that make use of resources within the XD ecosystem. Specifically, jetstream will:

  - Provide "self-serve" academic cloud services, enabling researchers or students to select a virtual machine (VM) image from a published library, or alternatively to create or customize their own virtual environment for discipline- or task-specific personalized research computing.
  - Host persistent VMs to provide services beyond the command-line interface for science gateways and other science services. Galaxy will be one of the initial science gateways supported.

- Enable new modes of sharing computations, data, and reproducibility. Jetstream will support Digital Object Identifier (DOI)-based publication and sharing of VMs via Indiana University's persistent digital repository, IUScholarWorks, as well as supporting all Globus services, including data transfer/sharing with Globus Connect, and identity federation through Globus Nexus.
- Expand access to the NSF XSEDE ecosystem by making virtual desktop services accessible from institutions with limited resources, such as small schools, schools in Experimental Program to Stimulate Competitive Research (EPSCoR) states, and Minority Serving Institutions. For example, VMs will enable use of Linux desktops from tablets.

- **Science Gateway Group provides science-enabling platform as a service and open source software.** SGG group manager Marlon Pierce serves as PI of the NSF-funded Science Gateway Platform as a service (SciGaP.org) project, which provides scalable, hosted services for science gateways developed by collaborators across the country. These services are based on the Apache Airavata software system. Apache Airavata is a top level Apache Software Foundation project, and SGG team member Suresh Marru serves as Apache Airavata's official board representative to the Foundation. During the reporting period, SciGaP services enabled over 40 scientific publications by providing access to 13 different advanced computing resources around the world. Since 2014, the SGG has published over 20 peer reviewed papers and conference proceedings about science gateways and open source cyberinfrastructure.
- **Advanced Visualization Lab improves the IQ series.** The IQ series represents the core of AVL's distributed visualization initiative, which uses commercial-off-the-shelf hardware and open-source software to provide low-cost, advanced visualization resources for the university community and beyond. The IQ name stems from four qualities: Inexpensive, Interactive, Immersive, and Interface (I-quad or IQ). A key quality of any IQ system is its ability to be relatively easily built, installed, and configured in a variety of spaces. During FY15, AVL improved its IQ-Wall standard (now offering higher performing monitors with improved color, better adjustment capabilities, more reliable electronic architecture, and stereoscopic viewing) and designed v2 of the IQ-Table (to be built and deployed in FY16) with improved performance, four times the resolution, and a more modern look.

Figure 1. IQ Wall and IQ Table 2

- **Programmable Immersive Peripheral Environment Systems (PIPES).** (Programmable Immersive Peripheral Environment System) is a tool that extends commonly used virtual reality systems in support cyber-physical applications. PIPES allows a developer to programmatically control high voltage sockets. Students and staff have used PIPES in virtual environments to simulate wind, heat, and scent conditions thereby improving the immersive quality and increasing their suspension of disbelief. First published in March 2015, PIPES has been demonstrated dozens of times across the nation during FY15 and has been well received by local and national practitioners.**]**

Figure 2. PIPES device and demonstration of technology

- **Research into Return on Investment in supercomputing and advanced cyberinfrastructure.** Is federal investment in advanced cyberinfrastructure a good investment of taxpayer monies? Do US taxpayers get a Return on Investment (ROI) that is greater than one, meaning the nation is receiving a positive return on their investment? PTI Executive Director Craig Stewart and a team of XSEDE researchers analyzed the costs and benefits of federal investment in XSEDE – the eXtreme Science and Engineering Discovery Environment – and determined that the ROI on federal investment is indeed greater than one. In a *Science Node* interview, Stewart pointed out that "this is very much a first attempt at measuring the ROI. Still, as far as we can tell, it is the first time anyone has ever published a ROI analysis on an entire CI center or organization."

Highlight: Spreading the good news about Jetstream to underserved communities

The Jetstream implementation team is striving to extend the reach of the NSF's eXtreme Digital (XD) program to researchers, educators, and research students who have not previously used NSF XD program resources – especially those in communities and at institutions that traditionally lack significant cyberinfrastructure resources.

Jetstream will be a novel cloud resource. In particular, Jetstream will deliver virtual Linux desktops to mobile devices and will deliver capabilities supporting research and research education at small colleges and universities, including Historically Black Colleges and Universities, Minority Serving Institutions, Tribal colleges, and higher education institutions in states eligible for the Experimental Program to Stimulate Competitive Research (EPSCoR).

When a researcher or student logs into Jetstream, they will have access to a library of public Virtual Machines (VMs) – including a generic Linux VM into which any application developer or user can add software of their own choosing – pre-configured to do a variety of important scientific tasks. They can use a pre-created VM and then save a personalized version to their private library. Researchers will also have the opportunity to save and publish VMs to support their scientific research. For software developers such as IU's bioinformaticians, Jetstream will provide an excellent mechanism for disseminating new software.

Jetstream is a collaboration between PTI, Texas Advanced Computing Center, the University of Chicago, the University of Arizona, University of Texas at San Antonio, Johns Hopkins University, Pennsylvania State University, Cornell University, University of Arkansas at Pine Bluff, University of Hawaii, the National Snow and Ice Data Center, the Odum Institute at the University of North Carolina, and the National Center for Genome Analysis Support. Craig Stewart is the PI of the Jetstream project, which is supported by NSF grant #ACI-1445604. Jetstream will go into production in early 2016.

4. PTI Goal: Create capabilities with which researchers at IU (and beyond) associate and collaborate

4.1. PTI Sub-goal: Be the 'partner of choice' within IU and the nation for creating and implementing cyberinfrastructure facilities (particularly when funded by a grant or contract focused on construction of a new facility or delivery of a new capability)

If one wanted to identify one key reason for PTI to continue existing on into the future (beyond keeping good faith promises made to the Lilly Endowment as part of the receipt of $43 million in funding), it would be the value within IU of functioning as the 'partner of choice' in creating and implementing cyberinfrastructure. IU's particular contribution to the concept of cyberinfrastructure is the role of people in enabling technology to support research, scholarship, and artistic creation. PTI brings together people across many organizational boundaries within IU, in order to serve the university and its constituencies.

This PTI sub-goal is tightly tied to Bicentennial Strategic Plan Goals Two, Three, and Five:

- Bicentennial Priority Two: Indiana University will renew its commitment to the university as a community of scholars that attracts and retains an excellent faculty
- Bicentennial Priority Three: Indiana University will engage in strategic hiring, investments in technology, and seed funding to support collaborative faculty research initiatives, with a focus on the grand challenges facing the state, the nation, and the world. It will continue to support the creative and scholarly activities of its artists and humanists.
- Bicentennial Priority Five: Indiana University will develop active partnerships with leading or complementary higher education institutions. IU will sustain active alumni chapters in all of its priority countries in support of study abroad, selective international recruitment, and faculty research and scholarship, especially in SGIS, the Lilly Family School of Philanthropy, and the Media School. It will complete the establishment of its Global Gateway Network to support these objectives.

Detailed explanations of PTI contributions to these Bicentennial Priorities within the context of the overall goal of PTI being the "partner of choice" are described below.

4.1.1. Bicentennial Priority Two: Indiana University will renew its commitment to the university as a community of scholars that attracts and retains an excellent faculty.

PTI, particularly the cyberinfrastructure facilities delivered and supported by the Research Technologies Division of UITS, is a highlight for Indiana University in recruiting and retaining top faculty talent. The role of PTI cyberinfrastructure is featured in a faculty recruitment video, "Supporting the building blocks of discovery: Indiana University's Advanced Cyberinfrastructure[7]." A recent report also summarizes views about IU's cyberinfrastructure from a group of faculty members who have worked closely with

[7] https://www.youtube.com/watch?v=cnlX6uhJVqI

Research Technologies and PTI as a whole and who have been recruited to IU, promoted within IU, or left IU within the five years prior to the completion of this report[8].

In the 1980s and early 1990s, the IU Bloomington and IUPUI campuses had a revolving door. Computationally savvy faculty members would come to IU, develop their research programs and reputations to a level of significant national or international visibility, and then be recruited away by another institution that then enjoyed the benefits of such researchers' prime years of scientific and grant-getting productivity. Today, IU brings in computationally savvy junior faculty members and retains and nurtures them to full professorship here, and recruits such faculty to come to IU from other institutions. As or perhaps more importantly, IU attracts and retains faculty members who may not be computational science experts – supporting their use of advanced CI tools for research, scholarship, and artistic activity.

Highlight: IU cyberinfrastructure matters to researchers, and they say so

Ask most any computer center and they will tell you that their services are important. To get a better sense of how important IU cyberinfrastructure resources are, and why, the Office of the Vice President for Information Technology (OVPIT) sponsored a qualitative study by an outside assessment organization.

During FY 2015, experts from the I-STEM Education Initiative of the University of Illinois at Urbana-Champaign interviewed IU faculty who had worked closely with the IU Pervasive Technology Institute and the Research Technologies Division of University Information Technology Services. The faculty interviewed had changed status in some way in the past five years: come to IU as new faculty member, left IU for another university, been promoted, or retired[8].

Faculty across many disciplines hailed the caliber of IU's hardware resources and its positive impact on the quality of research throughout the institution. Access and availability of these resources is also perceived positively, and junior faculty in particular consider these significant incentives for joining IU. Former faculty members (retired or transferred) also identify ongoing access to some of IU's resources as a significant benefit.

That there are people out there who like UITS, Research Technologies, and PTI services is all well and good. But what are the overall, average impressions? To measure these, OVPIT contracts with the IU Center for Survey Research to do a thorough and accurate sampling of community views. For FY2015, surveys were sent to 6,394 randomly selected people at IU Bloomington and 9,929 randomly selected people at IUPUI. The questions on the survey are primarily Likert opinion scales (1-5 rating scales with 5 always being the most favorable rating).

The overall summary of this survey is that people do indeed like PTI and RT services. In response to the question "Overall, how satisfied are you with the UITS research technology services available at IU?" faculty, staff, and graduate students gave an average score of 4.06 ± .13 out of 5 at IU Bloomington, and 4.17 ± .12 at IUPUI. At IU Bloomington, 29% of the faculty, graduate students, and professional staff made some use of IU's research cyberinfrastructure, while this same number was 32% for IUPUI – almost a third of the IUPUI research community!

Metrics identified in IU Bicentennial Plan related to this Priority include:

- Number and subjects of continuing intercampus networks and number of faculty members involved. This metric is included in Table 5.

[8] DeStefano, L. & Rivera, L. (2015). Office of the Vice President for IT and CIO at Indiana University cyberinfrastructure value assessment report. Champaign, IL: I-STEM Education Initiative University of Illinois at Urbana-Champaign. Retrieved from http://hdl.handle.net/2022/20568 .

- Number of academic conferences held at IU that bring scholars here from other institutions. A list of academic conferences held at IU and organized by PTI is in
- Table 2.

Table 2. Academic conferences and workshops held at IU that bring scholars here from other institutions

Conference	Topic	IU attendees (total)	Faculty attendees from outside IU
Bioinformatics Clinic	Current methods in genome assembly	20	5
Plant transcriptomics (Mockaitis)	International collaboration on plant transcriptomes	1	16
2014 UITS Summer School: Accelerate Your Science – An Introduction to High Performance Computing	Introduction to High Performance computing. Conducted in conjunction with the Virtual School of Computational Science and Engineering (http://www.vscse.org/)	40	3
Research Services Expo and Peebles Lecture	Research Expo introduced IU faculty, staff and students to the variety of research services available to the IU community via demos and consulting by RT personnel. The Peebles lecture presented by Felix Bachmann focused on software engineering.	167	1
Wikipedia Art & Feminism Edit-a-thon	Art+Feminism is a rhizomatic campaign to improve coverage of women and the arts on Wikipedia, and to encourage diverse editorship.	20	2
American Society for Eighteenth Century Studies Wikipedia Edit-a-thon	Held in memoriam of IU alumna Adrianne Wadewitz, a Wikipedia editor who had 50,000 edits to her credit. Participation on the IU campus and at ASECS Conference in Los Angeles, California.	25	20
Around Digital Humanities in 80 Days	Virtual project that highlighted digital humanities projects from around the world. IU was responsible for the African continent.	5	20
PRAGMA	Workshop on Pacific Rim applications and grid middleware assembly	2	78
TOTAL		262	145

In FY 2015, PTI also aided in the management of conferences and workshops held at other locations, described in the table below.

Table 3. Academic conferences and workshops organized by IU and other collaborators, held at locations other than IU

Conference	Topic	IU attendees (total)	Faculty attendees from outside IU	Non-IU attendees (total)
Workshop on High-Performance & Distributed Cyberinfrastructure for Polar Sciences: Applications, Requirements and Opportunities	NSF-sponsored workshop on use of distributed cyberinfrastructure for polar research applications, identifying strategies for supporting polar research in the field and after data collection	1	34	33
Immersive Visualization Bootcamp	Interactive workshop informing participants of techniques and tools to perform visualization using immersive virtual reality interfaces and displays	1	5	24
SC14 Visualization Infrastructure and Systems Technology Workshop	Workshop discussing the latest advanced visualization systems	2	34	59
Missouri Research and Technology Development Conference 2014	Regional conference hosted by Missouri Science and Technology Conference discussing all aspects of information technology	3	63	411
Open Science Grid All Hands Meetings	Distributed High Throughput Computing	10	60	NA
SPXXL Winter Workshop 2015	SPXXL is a user group for organizations that have large installations of IBM or Lenovo equipment. The focus of this meeting was engaging with new vendors and partners in technical NDA discussions (Lenovo, Intel, NVIDIA, and Mellanox). IU staff led all aspects of accommodation and meeting venue planning and contract negotiations.	3	0	32
Cray User Group Conference 2015	The Cray User Group is an independent, international corporation of member organizations that own Cray Inc. computer systems. Founded in 1978, CUG was established to facilitate collaboration and information exchange in the high-performance computing (HPC) community. IU staff led the overall event organization as chair of the CUG board.	6	4	202
SPXXL Summer Workshop 2015	SPXXL is a user group for organizations that have large installations of IBM or Lenovo equipment. The focus of this meeting was engaging with new vendors and partners in technical NDA discussions (Lenovo, Intel, NVIDIA, and Mellanox). IU staff led assisted in accommodation and meeting venue planning and organized the member site program contributions.	4	0	39
Gateway Computing Environments (GCE) 2014	GCE2014 was an accepted Supercomputing 2014 workshop. The GCE series, co-founded by RT's Marlon Pierce in 2005, provides a venue for science gateway developers and providers to make presentations of peer-reviewed research work in science gateway software development and operational strategies. GCE15 was also held and will be reported in the 2016 annual report.	3	NA	50
XSEDE14	The XSEDE conference series is a venue for researchers using XSEDE supercomputing and advanced research infrastructure, XSEDE support and operations staff, XSEDE outreach	10	NA	600

Conference	Topic	IU attendees (total)	Faculty attendees from outside IU	Non-IU attendees (total)
	and campus representatives, and other interested groups to present research work, participate in Birds of a Feather and panel sessions, and organize tutorials.			
XSEDE Science Gateway Symposium Series	The XSEDE Science Gateway Symposium Series is an online presentation series that presents a wide range of topics of interest to science gateway and scientific workflow developers and users. Archived presentations are available from https://www.xsede.org/gateways-symposium.	5	NA	200
IEEE/ACM Supercomputing Conference 2014 (SC14)	IU hosted a booth with interactive demos on a variety of projects currently underway in UITS Research Technologies.	50	1,250	1,300
LUG 2015	The Lustre User Group is a meeting currently sponsored by the OpenSFS non-profit which brings together users and developers of the open source Lustre file system. IU staff led the overall event organization chairing both the program and organizing committees.	2	2	198
HUF 2015	High Performance Storage System (HPSS) Users Forum is a meeting hosted annually by an HPSS customer site to engage customers, HPSS developers and other relevant HPSS staff for current issues and future plans discussions. IU staff were part of the Steering Committee and Technical Program Committee and annually lead the Burning Issues session (for tracking progress on customer reported issues).	3	NA	100
TOTAL		103	1,452	3,248

Highlight: Openly sharing data to address society's grand challenges

In this era of big data-driven science, working toward open data solutions with researchers facing similar challenges at other academic institutions becomes not just desirable, but necessary. For Indiana University Research Technologies—along with participation by the IU School of Informatics and Computing and the IU Libraries—being active in the Research Data Alliance (RDA) strengthens our contribution to solving data problems faced by our local, state, national, and international research communities.

The RDA is a global multidisciplinary consortium of research data scholars that are attempting to build the social and technical bridges that enable open sharing of data. Consortium members openly share data across technologies, disciplines, and countries to address the grand challenges of society.

RDA member scientists participate in active working groups and exploratory interest groups to share knowledge, discoveries, and solutions. By exploring and testing policies and standards, they enhance and facilitate global data sharing. Agreed-on solutions go to the technical advisory board for review, and then working groups set about delivering the solution to the community. Indiana University participates in the RDA through the Technical Advisory Board, the Organizational Advisory Board, and members in several interest groups and working groups.

4.1.2. *Bicentennial Priority Three: Indiana University will engage in strategic hiring, investments in technology, and seed funding to support collaborative faculty research initiatives, with a focus on the grand challenges facing the state, the nation and the world. It will continue to support the creative and scholarly activities of its artists and humanists.*

Indiana University distinguishes itself in many ways; among these now comes IU's Grand Challenge program[9]. As stated on the IU Grand Challenges web page, "*The IU Grand Challenges initiative is intended to advance knowledge, influence the future, and impact society. It is a broadly inclusive effort to address difficult societal challenges through the combined strengths of our scientific and liberal arts disciplines and our professional schools. Grand Challenges projects will traverse traditional disciplinary boundaries to begin to address our most pressing problems*."

IU's cyberinfrastructure (CI) – and the entire fabric of PTI's organization – is based on reducing barriers to innovation, discovery, improved health and quality of life, and artistic expression. A significant portion of PTI's activities is related to what can be considered grand challenges. The formalization of this initiative within IU will enable the Research Technologies Division of UITS, UITS as a whole, and all of PTI to focus CI research, development, deployment, and support activities on enabling IU to have significant national and international impact on the grand challenge topics selected for university-wide attention and investment. Already in FY2015 Vice President for Information Technology Brad Wheeler has created a blue-ribbon faculty taskforce to provide guidance for the future of IU's investments in and support of CI, mindful of the need to support the IU grant challenge program. This new 2015 CI Research Taskforce will create a strategic report that will assess progress made by UITS and PTI against a similar strategic taskforce report from 2005[10] and make strategic recommendations intended to guide IU in its research CI investments from now until 2025.

Some activities related to Bicentennial Priority Three – particularly items related to investment in *"...the physical and IT infrastructure necessary for twenty-first century research and beyond, through new and renovated laboratory space and continuing investments in cyberinfrastructure, with priorities based upon prospects for research productivity"* – are described later in this report. In this section of the document, we focus on PTI activities related to being the partner of choice. These are also relevant to Bicentennial priority three and the metrics defined for it, including:

- Amount and diversity of sponsored research
- Publication rate and demonstrated impact of faculty according to field-appropriate measures (already described in Table 1)
- Establishment of Grand Challenge groups and associated research funding
- Number of multi-campus sponsored research collaborations

4.1.2.1. Contributions of PTI overall to IU sponsored research

Table 4 shows grant awards to IU where a PTI Center was a formal partner (PTL & IUPUI 1999-2014) as well as sponsored program (research) awards to the PTI as an aggregate (in FY 2015 as reported by the IU Office of Research Administration). In addition to these sorts of activities, the Research Technologies Division of UITS offers a wide variety of services that are used by researchers in many disciplines and many responsibility centers at IU.

[9] Indiana University. 2015. Grand Challenges at Indiana University. http://ovpr.indiana.edu/grand-challenges1/grand-challenges/

[10] Wheeler, B.C. (ed.). Final Report of the Indiana University Cyberinfrastructure Research Taskforce. Indiana University. http://hdl.handle.net/2022/469

Table 4. Awards to PTI (from inception of PTL in 1999 and in FY 2015)

	Grant awards, total, to PTI
PTL & IUPUI 1999-2014	$81,489,841
PTI FY 2015	$10,053,716

4.1.2.2. Use of PTI / Research Technologies cyberinfrastructure systems and services and External Funding to IU

In FY 2015, IU's Office of Research Administration reported $540,738,922 in total awards (grants and contracts). IU's cyberinfrastructure contributed significantly to IU's grant competitiveness. Figure 3 depicts grants and awards to the entire university, subdividing the awards to IU according to use of IU cyberinfrastructure services by PI or Co-PI. Figure 4 depicts the same sort of grant and award information for the IU School of Medicine and other Clinical Affairs Schools (IU Schools of Dentistry, Health and Rehabilitation Sciences, Nursing, Optometry, Public Health – Bloomington, Richard M. Fairbanks School of Public Health – Indianapolis, Social Work).[11] Grant and contract receipts were subdivided into four categories:

- PI and Co-PIs include no one with an account registered on any CI system or service supported by Research Technologies Division of UITS
- PI and Co-PIs include at least one person with an account on IU's high performance computing (HPC) and cyberinfrastructure services (Big Red II, Quarry, Karst, Mason, Scientific Data Archive, Research File system, etc.)
- PI and Co-PIs include at least one person who uses databases, data resources, or collaboration tools delivered and supported by Research Technologies Division of UITS
- PI and Co-PIs include users of HPC and data /collaboration tools

It is certainly not the case that each and every grant award to a faculty member using PTI and RT resources depended critically on those resources; however, use of PTI and RT resources is widespread and is related to funding to major federal agencies (National Institute of Health, see Figure 5; National Science Foundation, see Figure 6). To get a sense of the importance of these facilities to the research finances of the university, we need to look a little deeper at grant funding processes themselves. Most grant awards consists of two parts: direct costs – the cost of actually doing the research proposed – and indirect costs – which are calculated as part of a formula that takes into account the cost of buildings, research instruments, and cyberinfrastructure. For Indiana University, the indirect rate for research grants is 56% – meaning for every dollar in direct research costs, facilities and administration monies are calculated at 56%. (For service contracts and grants, the indirect rate is 32%. And there are some grant awards that come without any indirect funding.) In FY 2015, funding for indirect costs was more than $150 million. This is much higher than the $10M or so that IU puts in to research cyberinfrastructure each year. We know from federal grant agency feedback that IU's cyberinfrastrtucture helps the competitiveness of IU researchers applying for grants. And the $10M that IU invests in research cyberinfrastructure a year is a small fraction of the funding that IU receives!

[11] http://www.iu.edu/initiatives/clinical-affairs.shtml

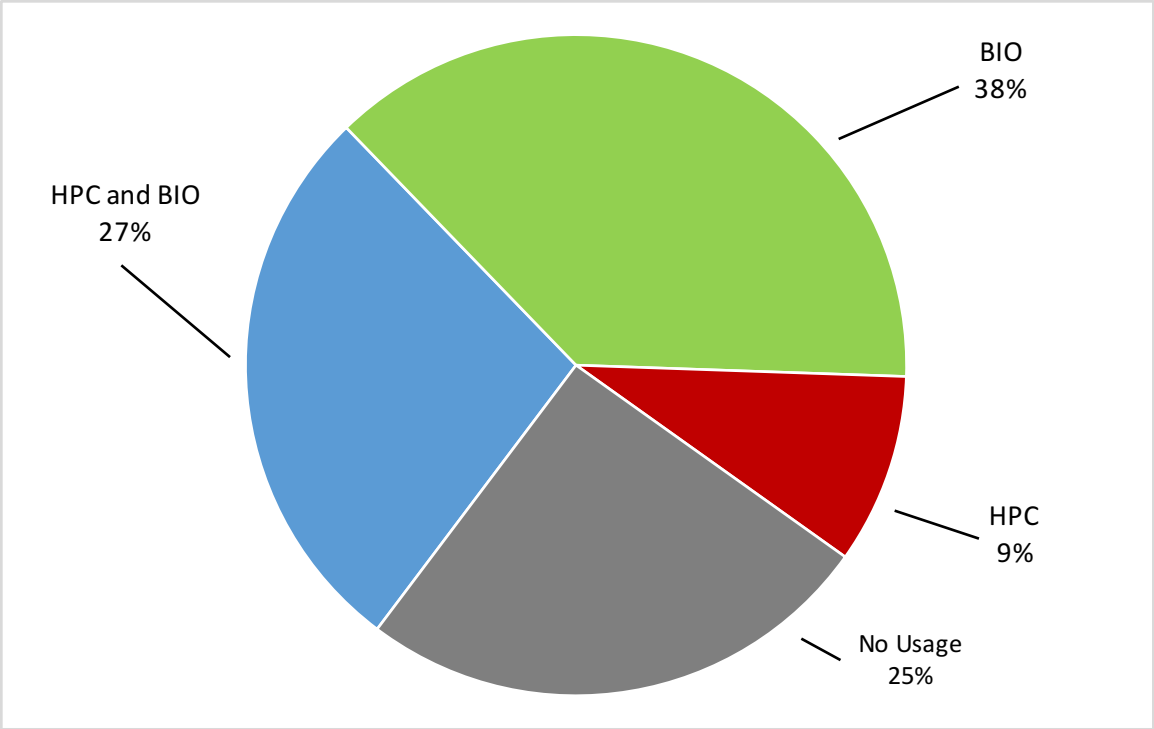


Figure 3. Grant funding to IU in FY 2015 associated with high performance computing systems (HPC), biomedical collaboration and data management services (BIO), or both.

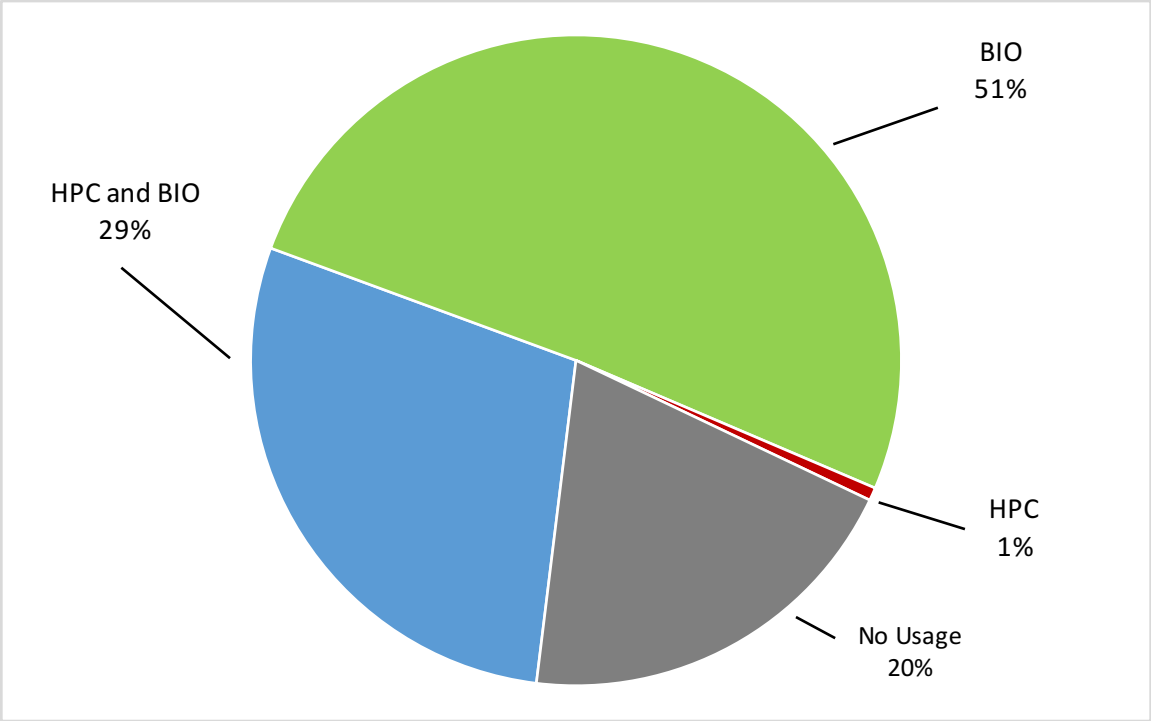


Figure 4. Grant funding to the IU School of Medicine and other Clinical Affairs schools associated with use of high performance computing systems (HPC), biomedical and data management services (BIO), or both.

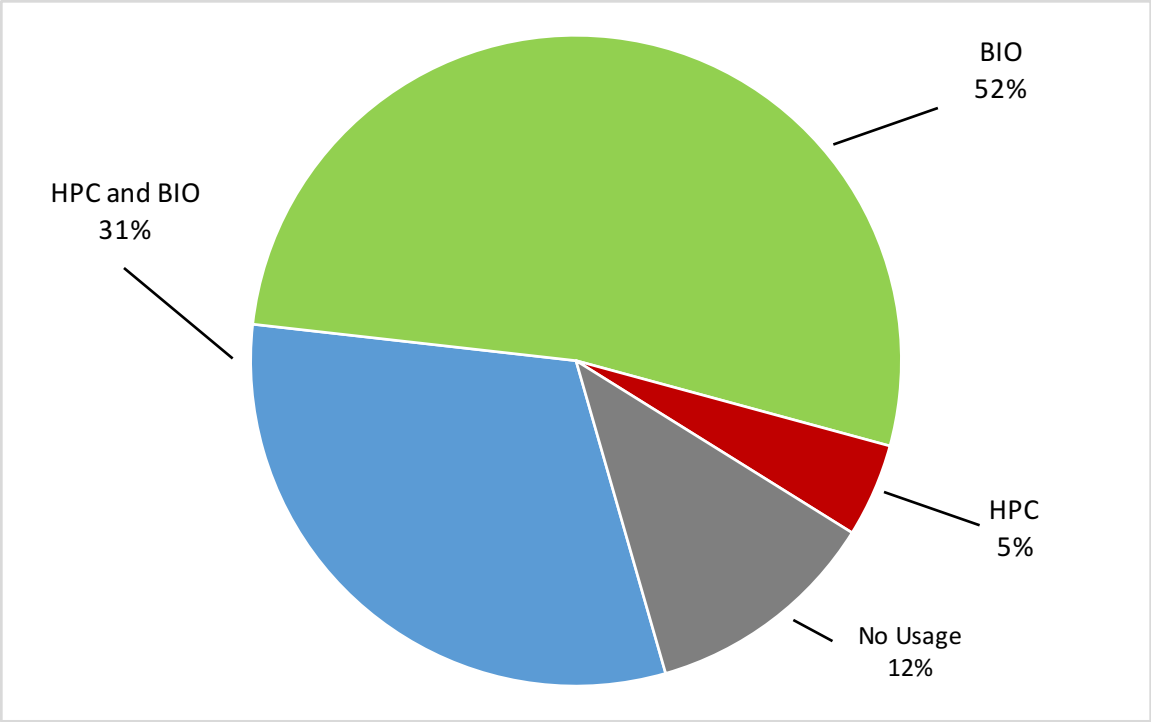


Figure 5. Grant funding from the National Institutes of Health associated with use of high performance computing systems (HPC), biomedical and data management services (BIO), or both.

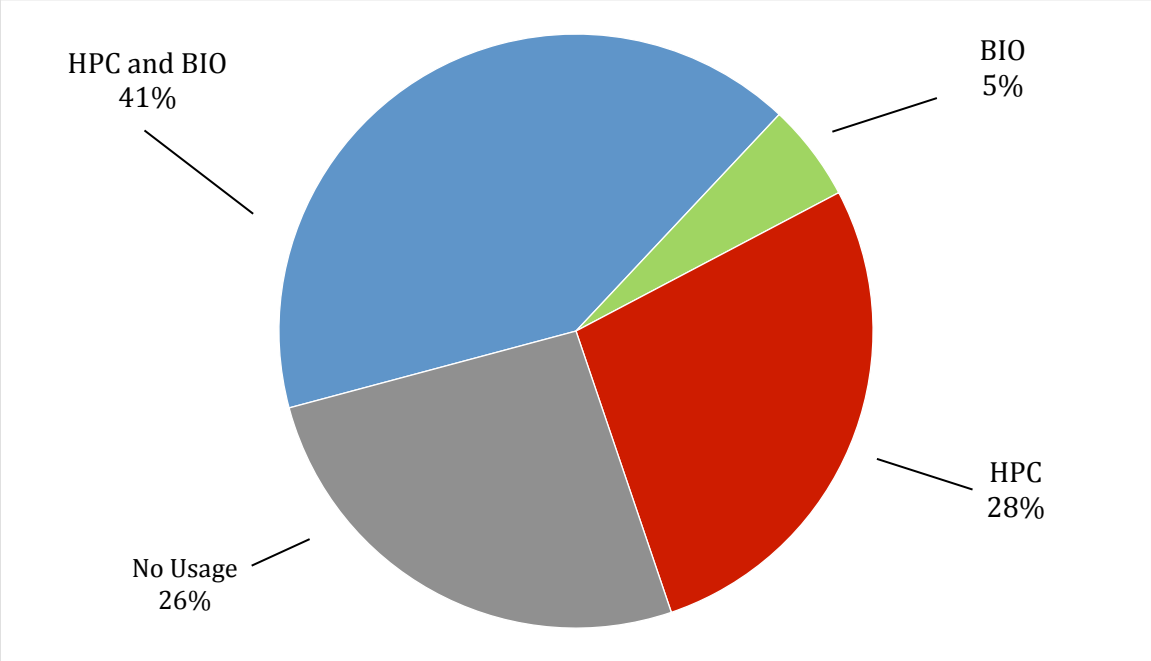
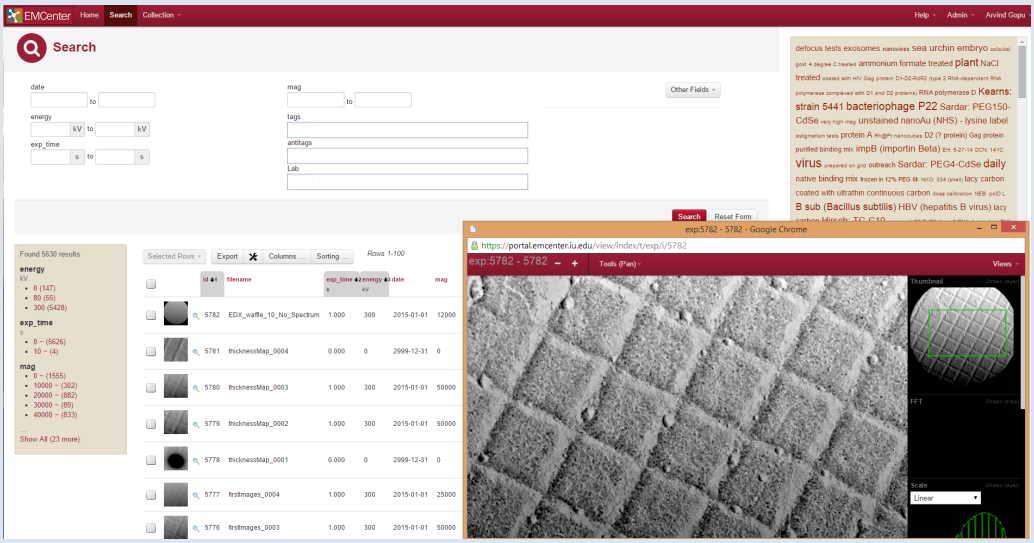


Figure 6. Grant funding from the National Science Foundation associated with use of high performance computing systems (HPC), biomedical and data management services (BIO), or both.

Highlight: Electron Microscopy Center – Scalable Compute Archive

The Electron Microscopy Center Scalable Compute Archive (EMC-SCA) is the primary resource for searching and download microscopy images taken by users of the IU EMCenter. Simply stated, the EMC-SCA makes it possible for IU researchers to view frozen, hydrated specimens at very high resolution. The computing expertise of these researchers spans a wide spectrum, from those comfortable with supercomputers and batch schedulers to more novice users.

EMC-SCA has enabled individual users of the EMCenter to access their data at any time via a secure portal – without having to learn about use of Scholarly Data Archive, Data Capacitor, Karst, or Big Red II (supported by Research Storage, High Performance File Systems, High Performance Systems, Scientific Application and Performance Tuning groups). Likewise, it has enabled the EMCenter Operations group to focus more on instrument and data quality, without having to worry about secure archiving of data.

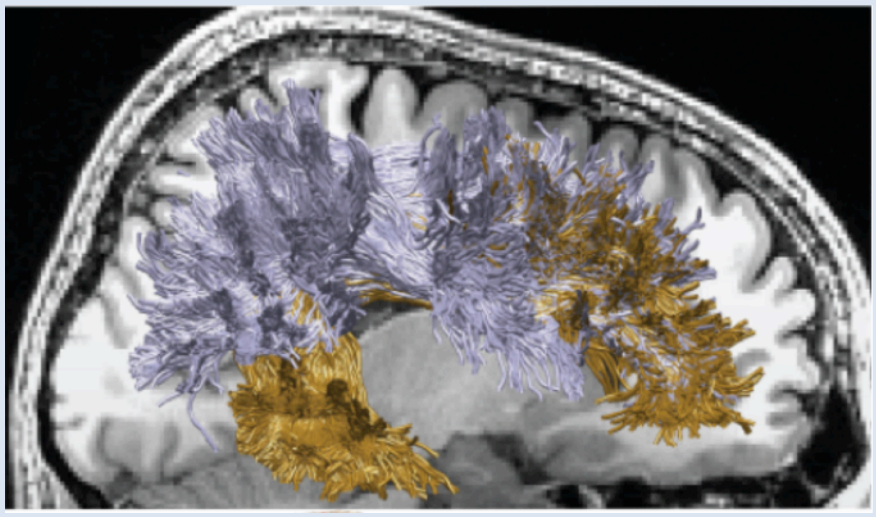


Screenshot showing Search and Image Explorer in EMC-SCA

Built-in frameworks include collections for creating logical collations of data products intended for publication, further research, instructional purposes, or processing tasks. Image Explorer also enables real-time interactive visual analysis of data products within a web browser. Future development includes a workflow framework that will enable rapid integration of data processing pipelines and data execution via custom user interfaces.

Highlight: Support for Franco Pestilli's research

Linear Fascicle Evaluation (LiFE) technology provides a method for precision mapping of the network of brain connections in living humans. LiFE has been successfully used to identify a major lost human white matter pathway, white matter fascicles dedicated to face- and place-processing, and precision diagnosis of white matter damage in individual with vision deficits.



Human brain with white matter tracts identified

LiFE uses cutting-edge, diffusion-weighted magnetic resonance measurements and automated fiber tracking methods to identify the network of brain connections in living human brains. LiFE was deployed on IU's Karst computing cluster in the spring of 2015, and plans are underway to install the software on Big Red II. In collaboration with Research Technologies, Dr. Franco Pestilli has improved the LiFE method – the software now runs about seven times faster and is more memory efficient. These efforts will yield a new generation of metrics to study the complex network of brain connections with the goal of improving fundamental algorithms that can map the human connectome.

4.1.2.3. Supporting research collaborations

The table below shows multi-campus sponsored research collaborations supported by PTI and the number and subjects of continuing intercampus networks.

Table 5. Number and subjects of multi-campus sponsored research networks led or supported by PTI

Name	Topic	Centers involved	PTI role	IU participation			Non-IU participation	
				Faculty	Non-faculty	Campus	Faculty	Campus
CTSC	Cybersecurity for NSF science	CACR	Lead	0	8	1	1	4
SWAMP	Software assurance	CACR RT	Support	0	4	1	2	3
RDA	Informatics and computer science	D2I	Support				> 4,000	Many international members
HTRC	Digital library	D2I	Lead	3	30	2	5	University of Michigan
SEAD	Scientific data preservation	D2I	Lead	1	20	1	20	UIUC, The Interuniversity Consortium for Political and Social Research
CTSI	New medical treatments	RT	Support			IUPUI IU	-	-
CIFASD/ Imaging Core	Fetal Alcohol Spectrum Disorder	RT (AVL)	Support	1	2	IUPUI	9	UCSD, SDSU, UCLA, Rivne Hospital, Emory University, Sanford Health, University of Minnesota, Khmelnitsky Hospital, University College London
NGVB	Gene therapy	RT	Support			IUSM		Many U.S. Institutions
ADNI	Alzheimer's disease causes	RT	Support			IUSM		59 acquisition sites
OSG	Multi-disciplinary	RT	Support	2	10	IUB IUPUI	15	UW, UCSD, UNL, UIC
XSEDE	Multi-disciplinary	RT	Support	6	6	IUB	620	UIUC, SDSC, PSC, TACC,
SciGaP	Biophysics, bioinformatics, computational chemistry, engineering	RT	Lead	0	10	IUB		UTHSCSA, UCSD
Geo-Gateway	Geophysics	RT	Support	0	10	IUB		NASA JPL, UC-Davis, UC-Irvine
NCGAS	Multi-disciplinary		Lead	15	50	IUB IUPUI	100	Many U.S. Institutions
SPPEXA	Exascale Computing	RT	Support			IUB	> 100	Many international members
DOSAR	Multi-disciplinary	RT	Support		3	IUPUI IUB	> 25	Bellarmine University, Iowa State University, University of Johannesburg, Langston University, LSU, Louisiana Tech University, University of Mississippi, University of Oklahoma, Universidade Estadual Paulista (UNESP) (SPRACE, GridUNESP), University of South Alabama, Sesquehanna University, University of Texas at Arlington
OSG	Multi-disciplinary	RT	Support				> 1000	Many US locations

Highlight: RT supports research on polar ice sheets

Polar research supported by RT has resulted in findings that Greenland's sub-glacial lakes are refilling with surface meltwater, and an extensive network of sub-surface drainage channels are moving this surface melt along the bedrock. This could affect ice sheet movement by adding heat to the ice at the sheet base. The figure below shows meltwater in an aerial photo from the Operation Ice Bridge mission.

RT polar research involves support for field researchers creating significant amounts of remote sensing data. Our primary partnership in this realm is with University of Kansas' Center for Remote Sensing of Ice Sheets (CReSIS), in support of NASA's Operation Ice Bridge and other initiatives. Data collection efforts from these missions have secured:

- Over 103 collections of Ice Sheet Radar Data in 2014-2015, over 675 TB total
- Over 60 flights with an IU Field Engineer in 2014-2015, and over 300 flights total in the Operation Ice Bridge program

From these developments, IU has been able to present on its technical implementation and data collection work to the community at:

- 2015 Polar Data Forum
- 2015 International Workshop on Advances in High-Performance Computational Earth Sciences
- Polar Data Hackathon
- NSF-sponsored workshop on HPC for Polar Science

IU's activities in this realm offer considerable opportunities for contributing to the support of grand challenge research in climate change. The data captured through activities in support of Operation Ice Bridge provides a year-by-year record of Arctic and Antarctic change, and IU's technical expertise can support multiple partnerships performing field research in polar areas.

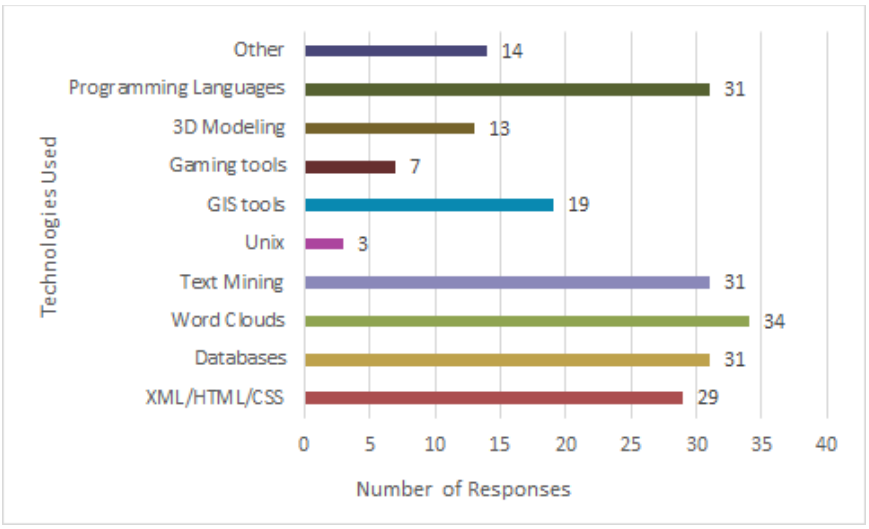


Figure 7. Technologies covered in digital humanities courses.

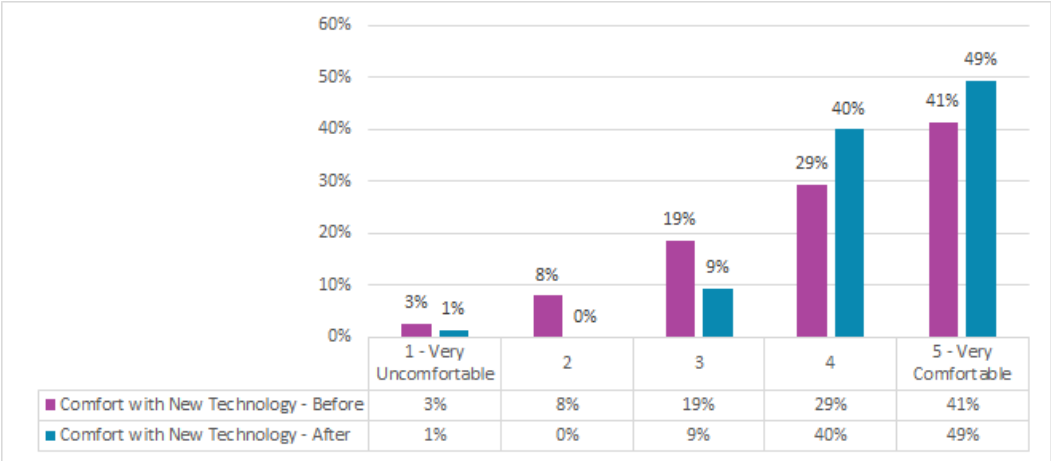


Figure 8. Student comfort learning new technology before and after taking a digital humanities course.

Highlight: Support of student pedagogical surveys on Digital Humanities courses

RT's support for digital humanities involved helping graduate students in the Information and Library Science Program design, distribute, analyze, and prepare presentations of survey results concerning teaching methods, contents, and outcomes in Digital Humanities courses across North America.

This work is timely given IU's movement to unify Digital Humanities offerings via a graduate certificate in the topic – and it was all the more impressive that students undertook not only to look at their own experiences, but also to reach out to other students being offered similar courses. This inclusion enabled a fuller assessment of the state of pedagogy in Digital Humanities in North America.

Two different surveys targeted students and instructors. RT's Cyberinfrastructure for Digital Humanities Group helped the students create streamlined surveys, navigate the IRB process, and assess the responses. Staff also provided feedback on two presentations: one for the College English Association (42% of respondents' DH courses are offered through English departments) in Indianapolis this March, and another presentation for the annual HASTAC (Humanities, Arts, and Science Collaboratory) Conference at Michigan State University in May.

None of the students had presented at these types of conferences before or collected data on human subjects. Responses yielded:

- 90 student responses from undergraduates through PhD candidates from the US and Canada
- 10 Skype interviews with instructors

From these surveys, students were able to present original research determining what works within a digital humanities course setting for both instructors and students:

- Final research projects with a technology application that reflects real working conditions in the digital humanities
- Community building within the classroom and with larger DH community
- Experimentation/creativity balanced with faculty support/guidance and clear goals/expectations
- Increasing students' ability to feel comfortable learning new technology

They also determined things that tend not to work in a digital humanities course setting:

- Survey courses that cover too much material (e.g., too many tools in too little time)
- Emphasis on theory rather than practical and creative application of technologies
- Open-ended projects without specific guidelines

With experience in courses and research at different universities and institutes (the University of California, Santa Barbara; the University of Victoria in Canada; the Digital Humanities Summer Institute; the Humanities Intensive Learning and Teaching Institute; and IU), the Cyberinfrastructure for Digital Humanities group was able to ground and extend student work in a wealth of experience.

4.1.3. Bicentennial Priority Five: Indiana University will develop active partnerships with leading or complementary higher education institutions. IU will sustain active alumni chapters in all of its priority countries in support of study abroad, selective international recruitment, and faculty research and scholarship, especially in SGIS, the Lilly Family School of Philanthropy, and the Media School. It will complete the establishment of its Global Gateway Network to support these objectives.

Particular action items related to Bicentennial Strategic Plan Goal Five include:

- IU will focus its international engagement efforts on its 32 priority countries and their leading institutions, establishing partnership agreements with leading or complementary institutions in all of these countries.
- IU will continue and enhance support for international students and for exchange programs that bring short-term faculty visitors to the university.

Highlight: IU experts teach programming at African Grid School

In developing countries of Africa, research and technology can lead to economic opportunity. The African Grid School, part of the African School of Fundamental Physics and its Application (ASP), is an exceptional opportunity for physics students in Africa to improve their research techniques by learning about grid computing.

IU's Rob Quick, manager of high throughput computing (HTC), and Kyle Gross, operations support lead for HTC, traveled to Senegal in August 2014 to teach in the African Grid School, which took place at Cheikh Anta Diop University in Dakar, Senegal. Quick and Gross became involved with ASP through their work with the Open Science Grid (OSG), which focuses on partnering with international science communities to share computing resources, knowledge, and skills.

Quick and Gross put in long days in Senegal, meeting with students well into the evening to answer questions and give technical advice. Both have years of experience supporting researchers in fields like physics, nanoscience, and biology. The trip was funded by the Distributed Organization for Scientific and Academic Research, and attracted nearly 60 physics graduate and postdoctoral students.

Based at IU Bloomington, the Grid Operations Center, part of IU's HTC group, provides a single point of operational support for the OSG. As part of their duties, Quick is the OSG operations officer and Gross is operations support coordinator. The HTC group helps IU researchers and national research communities solve complex computational problems by breaking them into individual jobs that run independently.

Highlight: Relationship with TU-Dresden

Research Technologies has an active collaboration with the center for information services and high performance computing (ZIH) at Technische Universität Dresden, Germany. As a part of this collaboration, two staff members from ZIH have worked at IU for multiple months during FY15. First Dr. Guido Juckeland taught a summer school introduction to high performance computing at IU in July 2014. Then Dr. Holger Brunst worked with RT staff members to improve the performance of scientific applications on IU's Big Red II supercomputer. He later also taught a summer school performance tuning of scientific parallel applications. In addition, an IU staff member has worked at ZIH for two weeks, as part of an NIH-funded Trinity grant project. This work led to a successful conference paper submission and will be published in 2015.

Table 6. PTI participation in international research and technical collaborations

International organization	Focus	Leaders from IU	PTI Centers Involved
AAMC GIR Leadership Institute	Training IT leaders for Medical Centers	Barnett	RT
AAMC GIR Steering Committee	Academic Medical Center IT Leadership	Barnett	RT
Apache Software Foundation	Leadership of Apache Airavata, support for Apache incubating projects, student mentoring through Google Summer of code	Marru, Pierce	RT
Coalition for Advanced Scientific Computing	Chair, Regulated Data Working Group	Barnett	RT
Cray User Group	President, collaboration and information exchange in the high-performance computing (HPC) community	Hancock	RT
DOE Computer Graphics Forum	High-end visualization for HPC and simulation for National Labs	Sherman	RT
EAGLE	Program Committee	Gniady	RT
European Life-science Infrastructure for Biological Information (ELIXIR) – Computing Competence Center	Distributed Computing Infrastructure for Life Science Data Analysis	Quick	RT
European Grid Infrastructure – External Advisory Committee	Distributed Computing	Quick	RT
HPSS User Forum	Steering Committee Member, Technical Program Committee Member	Kallback-Rose	RT
InCommon Steering Committee	Advisor for Research	Welch	CACR
Internet Civil Engineering Institute	Director	Sons	CACR
Internet2 HPRC-PAG	Steering Committee Member	Stewart	RT
Linux Clusters Institute	Steering Committee Co-Chair	Knepper	RT
Lustre User Group	Program Chair (6 years running), Promoting Lustre parallel file system and other open source file system	Simms	RT

International organization	Focus	Leaders from IU	PTI Centers Involved
	technologies.		
Molecule to Brain (MoBrain) – Computing Competence Center	Bridging microscopic and macroscopic scale e-Science Tools	Quick	RT
National Oceanic and Atmoshperic Administration Science on a Sphere Users Network	Research and educational institutions focused on application and advancement of Science on a Sphere technologies	Eller, Boyles	RT
Open Science Grid Council	High Energy Physics Research Consortium	Barnett, Quick	RT
Open Science Grid Executive Board	Distributed High Throughput Computing	Quick	RT
Open SFS	Board Member (3 terms), nonprofit organization dedicated to the promotion and development of the Lustre file system	Simms	RT
SCxy 2006-2016	Executive Committee Member	Link	RT
Research Data Alliance	Data management and preservation	Plale, Quick	D2I, RT
SCxy Steering	Steering member 2012-2019, International conference for high performance computing, networking, storage and analysis	Link	RT
SPEC Consortium	Area Director, HPG, Standards body for performance benchmarks	Henschel	RT
SPXXL Leadership	Current Board Treasurer and prior Board Vice-President, Large-scale scientific/technical computing	Henschel, Hancock	RT
SPEXXA Leadership	Advisory Board Member	Stewart	RT

4.2. PTI Sub-goal: Enable the translation of software innovations to practical use

Highlights of PTI activities in translation of software innovations to practical use include the following:

- **Science Gateway Group supports NASA earthquake research.** For the last decade, the SGG has worked closely with NASA earthquake researchers to develop science gateways and cyberinfrastructure. The geo-gateway.org science gateway resulting from this work provides interactive online access to NASA data products and simulation tools. Geo-gateway.org services and SGG support have recently been used in a study of the 2014 La Habra, California earthquake that forecasts a 99.9% likelihood of an magnitude 5 or greater earthquake in the greater Los Angeles area in the next three years. The study also increases understanding of the earthquake fault system and its geophysical mechanisms underlying the greater Los Angeles area: slower moving processes are causing significant damage to the aging underground infrastructure (such as water mains) in Southern California.
- **Science Gateway Group leads the XSEDE Science Gateway Program.** The Science Gateway Group (SGG) leads and contributes significant staff time to providing web- and desktop-based cyberinfrastructure that simplifies access to XSEDE resources. During the reporting period, SGG staff members have served as lead or supporting consultants on nine XSEDE gateway projects. SGG staff members also organized three XSEDE15 tutorials in July 2015 on the topics of science gateway building, science gateway usage, and scientific workflows. Forty-five people attended at

least one of the workshops. The workflow login node used for one of the workshops, hosted on IU's Quarry gateway hosting service, is now a persistent XSEDE resource and hosts four community-provided and maintained workflow tools.

- **CACR and HTC participate in securing software through the Software Assurance Marketplace (SWAMP).** CACR and the High Throughput Computing Group continue to provide the Software Assurance Marketplace (SWAMP), a $20 million DHS-funded facility that allows software developers and users to more easily identify and fix security vulnerabilities in their software, reducing the risks with using that software.
- **Center for Trustworthy Scientific Cyberinfrastructure.** Led by CACR, the Center for Trustworthy Scientific Cyberinfrastructure consortium is funded by NSF to lead its science community in securing the computational infrastructure critical to today's trustworthy science. In this role, CACR works with software development projects (e.g., Pegasus, SciGaP, Globus, NTP Foundation) to produce more secure software by advising them on good software development practices and the best way to implement new features.
- **NCGAS continues expanding access to genomic analysis software by researchers.** This includes the NSF-funded core purpose of NCGAS: to give researchers easy access to bioinformatics software packages on HPC systems capable of effectively running them, and to provide these packages in a menu-driven interface with Galaxy. Beyond pure research, NCGAS collaborates on two NIH Information Technologies in Cancer Research grants to make genomics analysis tools available to cancer researchers; the Trinity and GenePattern projects are centered at the Broad Institute and UCSF respectively. NCGAS works to improve these tools, but emphasizes making the tools broadly available.
- **AVL extends and further enhances its Collection Viewer application.** The AVL Collection Viewer software is an application built for collaboratively viewing and interacting with media collection(s). Media can include photos, videos, and audio clips. Commonly used in conjunction with the AVL's IQ-Table or IQ-Tilt systems, the software features an XML configuration file that allows exhibit creators to quickly and easily tailor the experience. Select new collections for FY15 included a beautiful exhibit featuring IU's Center for Network Science Places and Spaces Mapping Science collection, as well as a collection of African clothing from IU's Mathers Museum of World Culture. The Mathers exhibit debuted and was extremely well-received at the 2014 African Studies Association Annual Meeting in Indianapolis.
- **Open Science Grid Operations hosts network metric datastore and visualization for Large Hadron Collider Computing.** The OSG Operations group implemented a high availability database to collect performance-focused Service Oriented Network monitoring ARchitecture (perfSONAR) metrics for the Worldwide LHC computing facilities. This includes a Cassandra DB system that allows distributed high performance service management. The data collected can be immediately visualized via hosted services to troubleshoot active network issues, or historical data can be used to do long-term analysis of worldwide computing networking.
- **Text analysis with RNotebooks for beginners.** The CyberDH group has adapted algorithms from Matt Jockers into RNotebooks with markup that takes novices through the basics of text analysis (top ten counts, dispersion), working up to corpus clusters (dendograms) and using LDA. The code for this work currently resides on IU GitHub.

All told, PTI currently distributes a total of 31 open source software packages that are maintained on an ongoing basis and available for use by the US and global research communities as open source software.

5. PTI Goal: Impact the economic health and quality of life in Indiana – creating new jobs, nurturing new businesses

This particular goal gets at the root cause for the existence of PTI, as described in its mission statement:

> *The mission of the Indiana University Pervasive Technology Institute (PTI) is to improve the quality of life in the state of Indiana and the world through novel research and innovation and service delivery in the broad domain of information technology and informatics.*

This PTI goal of improving the quality of life in Indiana, the US, and the world is tightly related to IU Bicentennial Strategic Plan Seven.

5.1.1. Bicentennial Strategic Plan Goal Seven: Indiana University will contribute to the economic development and prosperity of Indiana by translating the discoveries and innovations of faculty, staff and students into new products, services, and companies…..

Metrics associated with Bicentennial Strategic Goal Seven include:

- Number and value of patents, licensing agreements, partnerships, and start-ups supported by IU

Continuing priorities related to Strategic Goal Seven include:

- Support regional business development in life science, technology, and related fields

Table 7. Patents awarded to faculty and staff with a relationship to PTI

Description	Patent #	Relationship to PTI	Web address
Wireless Network Radiolocation Apparatuses, Systems and Methods	**US 20090054106 A1**	Steven Wallace and Danko Antolovic were PTL staff members at the time of the patent filing	http://www.google.com/patents/US20090054106
Compression system and method for accelerating sparse matrix computations	**WO 2007095516 A3**	Professor Andrew Lumsdaine and academic research associate Jeremiah Willcock were affiliated with PTI at the time of the patent filing; patent partly owned by IURTC	https://www.google.com/patents/WO2007095516A3?cl=en&dq=lumsdaine+patent&hl=en&sa=X&ved=0CB0Q6AEwAGoVChMIvuj15rr0yAIVyCoeCh2XLgGu
Total – 2 Patents awarded with some relationship to PTI			

Table 8. Indiana-based startup companies and organizations established with some sort of engagement or assistance from PTI from inception of PTL in 1999 that are still active as of the end of FY2015. (Life sciences companies are indicated with an *)

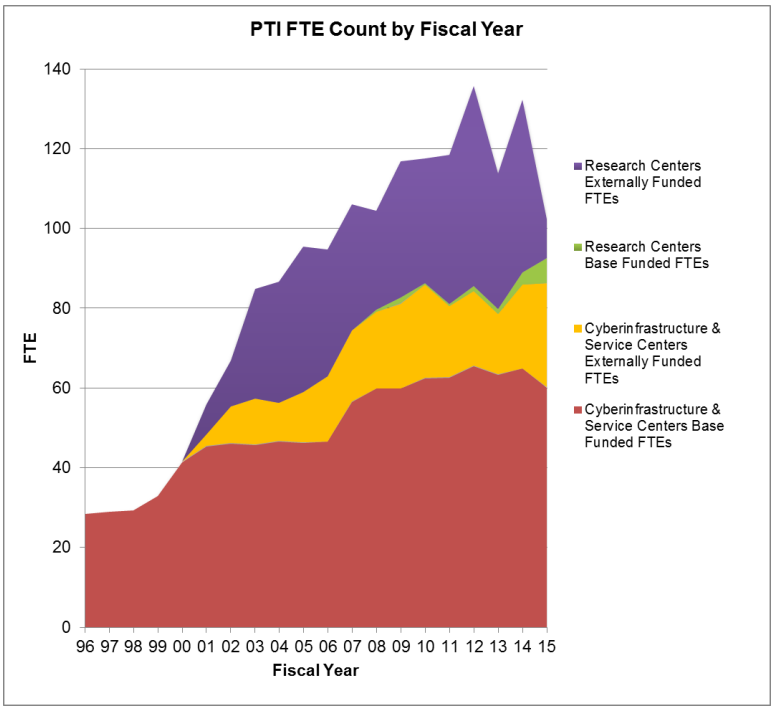
	Description	Relationship to PTI	Web address
Bloominglabs, a 501©3 not for profit which is Indiana's first makerspace.	Makerspace, robotics	Founded by a group of people including PTI staff, events annually sponsored by PTI.	http://bloomingtontech.com/project/bloominglabs/
Chalklabs	Data Analytics	Company founded by students of PTL Fellow Dr. Katy Boerner	http://bloomingtontech.com/project/chalklabs/
Precise Path Robotics	Autonomous robotic lawnmowers	Started with IP (Intellectual Property) created by PTL staff	
Wisdom Tools	Educational games	Early leaders included faculty with PTL affiliations	http://www.wisdomtools.com
Total – 4 startups with some affiliation to PTI			

Table 9. Companies other than startups that operate within Indiana and which benefit from some sort of support or engagement with PTI from inception of PTL in 1999 that are still active as of the end of FY2015. (Life sciences companies are indicated with an *)

	Description	Relationship to PTI	Web address
Cigital	Cybersecurity consulting and analysis	Branch opened in Bloomington as a result of relationship between Cigital CTO and former PTL Science Director Dr. Dennis Gannon	http://bloomingtontech.com/project/cigital-inc/
Cummins Inc.	Porting computational fluid dynamics simulations to GPUs on Big Red II	Research Support	http://www.cummins.com/
Naut Inc.	Scalability testing of algorithms on Karst and Big Red II	Research Support	http://www.nautinc.com/
WS02	Open Source Enterprise Software Development; opened branch office in Bloomington	Strategic partnerships with PTI's D2I Director Beth Plale, DSC Director Geoffrey Fox, and RT members Suresh Marru and Marlon Pierce	http://wso2.com/
Total – 3 companies operating in Indiana with some relationship to PTI			

One of the most important ways in which PTI enhances the economic health and quality of life in Indiana is by being successful in the highly competitive process of winning federal grants and contracts, and creating new high quality jobs in Indiana as part of IU. Such jobs have an average salary greater than the overall average in Indiana, add to tax roles, and often bring highly qualified professionals from other states or nations to Indiana, where they very often settle down and stay their entire careers.

Figure 9. PTI employment over time, measured in Full Time Equivalents (FTEs), showing positions funded by external grants and contracts.



Highlight: HPS group helps Cummins improve combustion simulation to lower pollutants

Located in Columbus, Indiana, Cummins Inc. designs and manufactures diesel engines used all over the world. To decrease pollutants released by its engines, Cummins is pursuing chemical kinetic mechanisms that represent conventional and next-generation fuels in devices like internal combustion engines.

IU's High Performance Systems (HPS) group assisted Cummins by using graphic processing units (GPUs) to calculate reaction rates. Without this GPU-based approach, solving the combustion chemistry of complex fuels inside a combustion chamber is impractical. With the GPUs, it is now possible to improve the ignition predictions of new fuels and understand the formation of soot pre-cursors.

As a result of this work, Cummins has developed a one-way coupling approach between nozzle flow and spray calculations that can account for variations in nozzle designs. Spray formation and hole-to-hole variations in the nozzles can be captured using this technique. Droplet formation and atomization can also be simulated.

This work was made possible by an earlier partnership of Lawrence Livermore National Laboratory, Indiana University, and Cummins to adapt engine simulation software from Convergent Science (the top maker of engine simulation software) to GPUs.

6. PTI Goal: Support the development of a 21st century workforce within the State of Indiana

PTI supports the development of a 21st century workforce in a variety of ways. One of the primary ways is through education offered by faculty with a PTI affiliation. As stated earlier, course delivery activities result in academic credits at IU, and degree-granting programs are offered primarily through PTI-affiliated centers that are also subunits of the IU School of Informatics and Computing (D2I and DSC in particular). PTI provides a number of services and facilities that support the development of a 21st century workforce in Indiana by facilitating success and innovation by current IU students, and by spurring interest in STEM disciplines (Science, Technology, Engineering, and Mathematics) through K-12 outreach programs.

This PTI goal is closely related to IU Bicentennial Strategic Plan Goal one:

- Bicentennial Strategic Plan Goal One: Indiana University will continue to enhance its commitment to student success…

6.1.1. *Bicentennial Strategic Plan Goal One: Indiana University will continue to enhance its commitment to student success…*

In 1955 astronomy professor Marshall C. Wrubel was appointed as the first director of the IU Research Computing Center. One of the first things Dr. Wrubel did was determine that his own graduate students, and the graduate students of others, were as worthy of using IU's electronic research computer as any IU faculty member. Thus began a 60-year (and counting) commitment to support for IU student achievement by the research computing center and its successors.

Current critical services offered to undergraduate and graduate students of IU include access to software (analytical, geographic information system, mathematical, and statistical) and access to and use of supercomputers.

IU supercomputing resources are described in detail in Appendix 2 (section 3). Graduate and undergraduate students have open access to Karst, IU's newest computing resource brought online in October 2014 (and prior to that a similar resource, Quarry). These resources are available without usage fees to support research, artistic, and scholarly endeavors related to projects in the classroom, the lab, or art and design studio. Similarly, IU's largest computing resource, Big Red II, and a specialized large-memory system, Mason, are both open to graduate students by default and undergraduate students with a faculty sponsor.

- **Access to and use of database systems.** The IU research database environment is described in section Appendix 2 (section 3). As with IU's supercomputing resources, graduate and undergraduate students have open access to the Research Database Complex (RDC) to host data in an Oracle or MySQL relational database without usage fees. Students can also leverage the RDC as a backend to web applications hosted within the environment or elsewhere.

- **Use of advanced storage systems.** IU's data storage systems are described in Appendix 2 (section 4).
- **Access to the SDA.** Graduate students and sponsored undergraduate students have access to the Scholarly Data Archive, which provides large capacity, long-term storage in IU's tape-based archival system. The 50TB default quota is extended students, faculty, and staff alike.

- **Access to DC2 and DC-WAN.** IU students, faculty, and staff using IU's HPC resources by default receive access to Data Capacitor II (DC2) and Data Capacitor WAN (DC-WAN), high capacity, high bandwidth file systems for the short- to mid-term storage of research data. Both systems use the open source Lustre file system, present on over 60% of the world's top 100 supercomputer systems. DC-WAN permits a file system mount across long distance to enable geographically distributed workflows and new ways of collaborating.
- **24/7/365 use of the entire suite of advanced visualization technologies.** Available technologies include ultra-resolution IQ-Walls, interactive and collaborative IQ-Tables and IQ-Tilts, 3D scanning equipment, spherical displays, and a variety of interfaces and displays that support virtual and mixed reality. Of particular note, IU Bloomington has seen increased student use of IQ-Walls in public spaces (e.g., the main library). IUPUI has seen tremendous uptake from students because of their close partnerships with Informatics. Informatics students met and utilized the provided visualization technology nearly daily, and often on weekends and evenings. A loaner program for portable equipment (the most popular being the Oculus Rift Development Kits) affords additional opportunities for independent learning and exploration.
- **Use of the GitHub Enterprise Service.** IU is the first academic institution to provide the GitHub Enterprise Service for distributed source code control, software development, and collaboration. The git distributed version control system allows considerable flexibility and ease of collaboration in a networked environment. This service has seen considerable uptake across the university, not only from the School of Informatics and Computing, but also in numerous academic units as well as in administration. Currently github.iu.edu hosts 11,882 repositories owned by 3,054 users, supporting student projects and assignments, departmental web services, faculty collaborations, and enterprise software development.

Table 10. Student users of IU's advanced cyberinfrastructure (hundreds of additional students, ranging from middle school to graduate school, participated in tours and demonstrations of IU's advanced visualization systems)

Type of system	Undergraduate student users	Graduate student users	Total student users
Users of statistical and mathematical software	40*	186*	226*
Supercomputers & computational systems	36	558	605
Advanced storage systems	282	1157	1477
Database systems	11	42	53
Advanced visualization systems	144	73	217
RT GitHub code repository	1640	1154	2794
Google Summer of Code participants	0	8	8

*It is important to note that these numbers only include the usage of Maple, Mathematica, Matlab and SPSS on the central research systems (BR2, Karst and Mason). Data for STCs and IUanyWare could not be obtained. Additionally data for SAS, Minitab, etc. could not be obtained as these software packages don't use a license server. There are basically five ways that students can use the Stat/Math software: 1) in STC labs, 2) on IUanyWare, 3) on central research systems, 4) purchasing a copy from the bookstore, and 5) purchasing a copy directly from Research Analytics. The numbers in Table 11 only take into account a subset of the software titles (from central research systems). The actual number of student users almost certainly multiple thousands.

Highlight: Google summer of code

To teach real-world open source, open community practices, the Science Gateways Group engages students through the Google Summer of Code (GSOC) project. The students contribute to the Apache Airavata science gateway framework. Since 2012, Apache Airavata has sponsored over 20 GSOC students, including four IU graduate students and other students from around the world. The program has attracted one student to join IU as a graduate student, and one to join as a full-time staff member. GSOC also provides RT with a mechanism for engaging collaborating faculty as co-mentors. In Summer 2014, SGG mentored 4 Google Summer of Code students total.

Overview of 2015 Student Projects

- Integrate SEAGrid GUI with Apache - Dimuthu Upeksha, University of Moratuwa, Sri Lanka
- GenApp Integration with Apache Airavata - Abhishek Kapoor, Priyanshu Patra, Indian Institute Of Technology (IIT) Kharagpur
- Integrating DataCat system with Apache Airavata - Supun Nakandala, University of Moratuwa, Sri Lanka
- Securing AIRAVATA API - Hasini Gunasinghe, Purdue University
- Evaluate Apache Airavata Metadata storage and explore alternative solutions - Douglas Chau, State University of New York, Binghamton
- Integrating Apache Mesos with Science Gateways via Apache Airavata - Pankaj Saha, State University of New York, Binghamton
- Benchmarking Resource Usage of Airavata's Applications - John Weachock, State University of New York, Binghamton

Papers Resulting from GSoC 2014 and 2015:

- Brookes, E. H., Kapoor, A., Patra, P., Marru, S., Singh, R., and Pierce, M. (2015) GSoC 2015 student contributions to GenApp and Airavata. Concurrency Computat.: Pract. Exper., doi: 10.1002/cpe.3689.
- Pankaj Saha, Madhusudhan Govindaraju, Suresh Marru, Marlon Pierce,"Integrating Apache Airavata with Docker, Marathon, and Mesos" accepted for publication in Concurrency and Computation: Practice and Experience, 2015.
- Brookes, Emre H., Nadeem Anjum, Joseph E. Curtis, Suresh Marru, Raminder Singh, and Marlon Pierce. "GenApp module execution and airavata integration." In *Proceedings of the 9th Gateway Computing Environments Workshop*, pp. 9-12. IEEE Press, 2014.

6.1.2. Employment, education, and practical experience for IU students

Two PTI research centers are part of the School of Informatics and Computing, headed up by leading IU faculty members. Such centers have the education of undergraduate and graduate students as a core part of their mission. The other PTI centers also provide employment and practical research experience for undergraduate and graduate students.

During the first 15 years of PTL and PTI activities, PTI provided research experiences to 203 students, including: 66 PhD students and post-doctoral fellows, 116 master's degree students, and 21 undergraduate students.

Table 11. Students employed by PTI centers, including tallies of students who have completed degrees during FY 2015

Center	Undergraduate student interns / employees	Undergraduate student interns / employees graduating	Masters student graduate assistants / employees	Masters students completing degrees	Ph.D. student graduate assistants / employees	Ph.D. students completing degrees	Total number of students
CACR	0	0	Vineeta Sangaraju, NaLette Brodnax, Rahul Sinha	0	0	0	3
D2I	0	0	3	1	10	2	13
DSC	0	-	4	-	10	0	14
NCGAS	0	0	0	0	1	0	1
RT	Steve Bird (HPS) Scott McClary (SciAPT)	0	Shameera Yodage, Nipurn Doshi, Higgins	Lahiru Ginnaliya Gamathige Ben Fulton (SciAPT)	Huian Li (SciAPT) Michael Young (SciAPT) Robert Henschel (SciAPT)	0	###___
AVL PA staff (Boyles)				1			1
AVL interns & GAs	3	0	1	1	0	0	4
GSOC	0	0	8	0	0	0	8

One particular note on graduate student success is that Richard Knepper, manager of Campus Bridging and Research Infrastructure, has been admitted to candidacy for a PhD in the School of Informatics and Computing.

6.1.3. Education and outreach activities that interest and inspire the scientists and technologists of the future

Of course, people don't generally wake up one morning when they are 16 or 17 and fire up a supercomputer.

Highlight: PTI's Ready, Set, Robots! program continues to inspire youth

Encouraging youth to enter a field of study in science, technology, engineering, or mathematics (STEM) continues to be a focus of the outreach and education component of PTI. The Ready, Set, Robots! (RSR) program, now in the 9th year, is one of the many programs IU offers in the area of K-12 STEM outreach.

The 2014 and 2015 RSR 2-day camps were held at IU Bloomington and introduced youth to computer programming using Lego® Mindstorm® robots. In addition, campers dabbled in public speaking, experienced advanced visualization through use of the IQ-Wall in the Cyberinfrastructure building for final presentations, and toured the Data Center where high performance computers such as IU's Big Red II and Mason are located. 56 students attended the 2014 camp, 52 students attended the 2015 beginner camp, and an estimated 120 friends and family attended the Robot Grand Challenge where the campers present the results of their newly-learned programming knowledge. In addition to the 2-day camp, PTI continues to reach out with the RSR program through other venues like the Minority Engineering Advancement Program at Indiana University Purdue University Indianapolis (IUPUI), Conner Prairie Curiosity Fair in Fishers, Indiana, and Celebrate Science at the Indianapolis State Fairgrounds. Through these venues we estimate reaching another 400+ students and families. We learned of the impact of our program during the 2015 beginner camp when a returning camper announced he was accepted and would be attending an advanced engineering program at a prestigious engineering school on the east coast.

The 2014 camps garnered national recognition when the associated press picked up a local news story. News of the program quickly spread from coast to coast, appearing in the Washington Times and SFGate and a multitude of publications in between. In late 2015, we look forward to hosting the first "Advanced RSR Camp" at IU Bloomington with a new set of objectives and a focus on mathematics.

7. PTI Goal: Offer services that enhance enable new innovations and accelerate research by the IU research, scholarly, clinical, engineering, and artistic communities

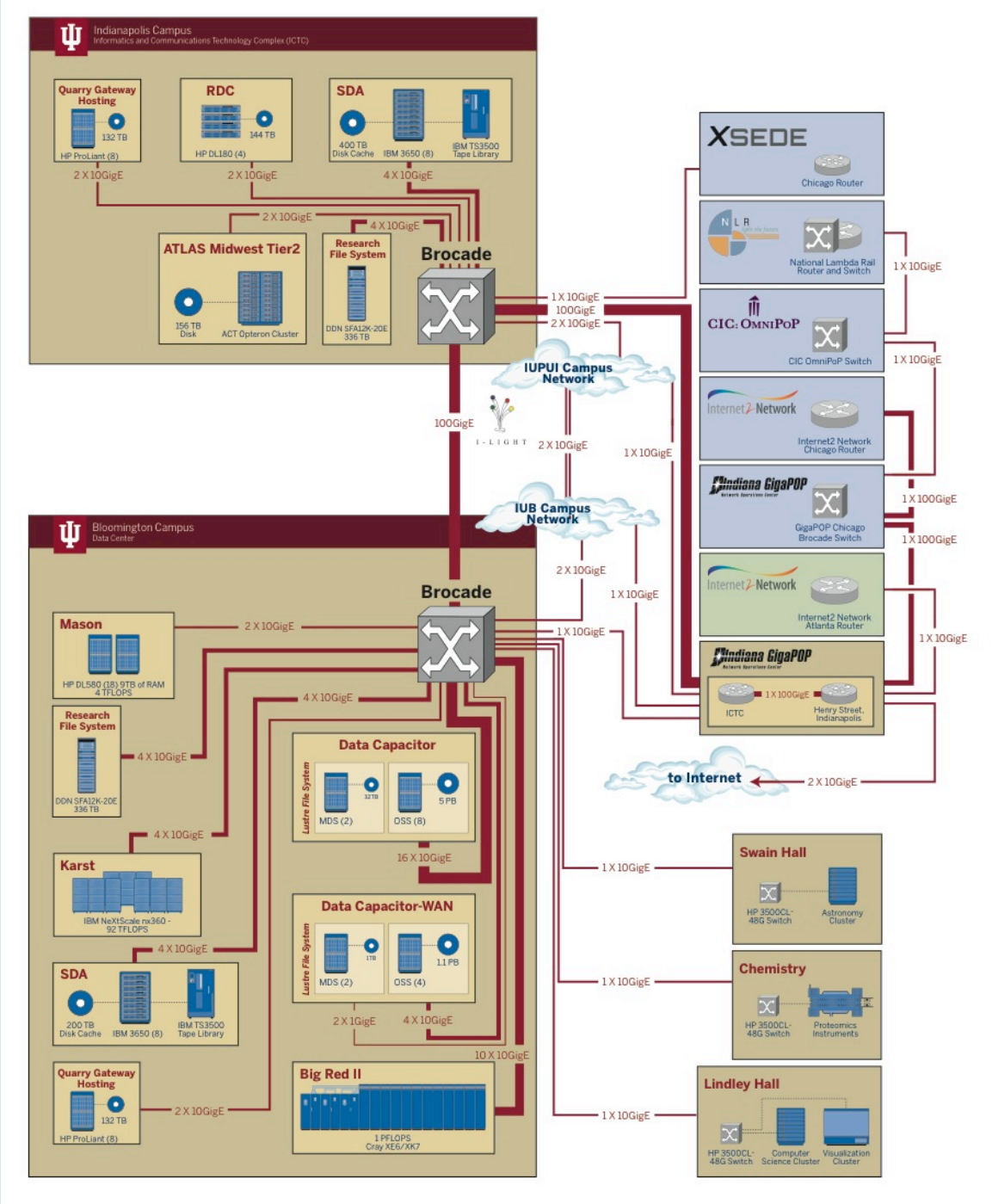
The Research Technologies Division of UITS and the National Center for Genome Analysis Support (NCGAS) are the two centers of PTI referred to as Cyberinfrastructure and Service Centers. RT and NCGAS engage in activities particularly relevant to the following IU Bicentennial Priorities and Continuing Priorities:

- Bicentennial Priority Three (continuing priority of "The Centrality of Information"): Ensure that the Principles of Excellence are supported by outstanding information technology and information resources
    - Pervasive deployment of IT. Ensure information technology is pervasively deployed at IU by leveraging and continuing the support of the university's long-standing and internationally recognized excellence in information technology services and infrastructure.
- Bicentennial Strategic Plan Goal Six: Indiana University and IU Health, including Riley Hospital for Children, will strategically invest in world-class research and training in selected areas of the health sciences – with emphasis on cancer, cardiovascular disease, and the neurosciences – through targeted hiring, collaboration, and infrastructure investments which have the potential to be translated into new and improved treatments, cures, and procedures. Recognizing our responsibility to take a leadership role in improving health in our state, IU will continue to invest and coordinate its efforts in public health and will seek to work with state government agencies to help address Indiana's public health problems.
- Bicentennial Priority Eight: Indiana University will explore and pursue the feasibility of establishing new programs in design and engineering on the IU Bloomington campus and technology programs on the regional campuses to meet regional needs.

Relevant PTI activities – through the actions of the two cyberinfrastructure and service centers – have aided IU innovations in many ways, described in more detail below.

Highlight: Overview of RT cyberinfrastructure

Schematic diagram of IU cyberinfrastructure showing network connections between IU and other national networks and network connections and cyberinfrastructure within IU.



7.1.1. Bicentennial Priority Three / Continuing priority of "The Centrality of Information": Ensure that the Principles of Excellence are supported by outstanding information technology and information resources.

This continuing priority is further explained as: Pervasive deployment of IT. Ensure information technology is pervasively deployed at IU by leveraging and continuing the support of the university's long-standing and internationally recognized excellence in information technology services and infrastructure. There are a number of sub-items for this continuing priority identified in the IU Bicentennial Plan, each addressed below with two exceptions. Those exceptions are the following sub-items:

- Maintain IU's leadership role in network management and cybersecurity in Indiana, nationally, and internationally. This has already been discussed earlier under CACR activities.
- Implement Empowering People: IU's Strategic Plan for IT, with particular focus on systems for the use of institutional data, supporting student success, and facilitating academic processes. A mapping of PTI activities to the action items called for in "Empowering People" is included in Appendix 3.

7.1.1.1. Ensure that IU continues to provide an outstanding, flexible, and secure IT infrastructure for students, faculty, and staff

RT and subsequently CACR, with a transfer of responsibility late in FY15, bear primary responsibility for maintaining Health Insurance Portability and Accountability Act (HIPAA) alignment for UITS services. This includes periodic controls and documentation revision, staff training and workshops, regular external audits, and coordination with Compliance, Security, Internal Audit, and the Data Stewards. It also encompasses establishing and maintaining institutional standards for securing electronic protected health information (ePHI), responding to incidents, and assisting UITS units as they put in place the appropriate controls and other requirements to sufficiently secure ePHI. This service has proven useful and needed by a number of units across UITS and has become part of the IT risk management landscape for IU.

PTI's activities in this have firmly established IU as a national leader in regulatory alignment of IT systems for HIPAA and FISMA (the Federal Information Systems Management Act). HIPAA alignment is important to UITS' research relationship with Clinical Affairs schools, researchers who work with ePHI on all campuses, and UITS' growing relationship to IU Health. The risk for non-compliance can be high: In 2013, a breach of the personal health information from 6,800 people at Columbia University and NY Presbyterian Hospital resulted in a fine of $4.8M.

During FY15, the following certificates were supported in achieving their HIPAA alignment: Box, CAS, Conveyant, IUanyWare, axiUm (on IUanyWare), New RFS (Geode), and WebServe/CHE.

7.1.1.2. Invest in cyberinfrastructure for education and research that emphasizes flexible and scalable high speed computation, massive data storage, and extensive high-speed network connectivity that enables education and research

When the UITS Research Technologies Division proposed the purchase of Big Red II, we made a commitment to offer training, information, and support services to increase the diversity of disciplines and sub-disciplines that make use of the system. In particular, we set a goal of having Big Red II used by

at least 150 disciplines and sub-disciplines practiced at IU. PTI met and exceeded this goal, as shown in **Table 12** below.

Perhaps as interesting as the diversity of disciplines and sub-disciplines that make use of Big Red II is the overall diversity of users of IU's advanced cyberinfrastructure. According to IU's web pages, there are a total of 381 recognized disciplines and sub-disciplines of science, engineering, humanities, scholarly, artistic, and creative endeavor practiced at IU. Out of those 381, well more than half – 243 – are represented by users of IU's advanced cyberinfrastructure. The diversity of Karst users is greater than Big Red II, representing the fact that Karst meets the computational needs of many researchers, and that Big Red II is both more powerful in its capabilities and more demanding in terms of the amount of expertise required in order to use the system effectively.

Educational programs such as the "Supercomputing for Everyone" educational series provide very effective training on Big Red II. But where a researcher's needs or student's needs can be met by Karst, the fact that it is the less expensive of the two systems (on a per-unit-of computing basis) means use of Karst makes effective use of IU financial resources. In fact, as a result of faster clock rates, Karst completes many serial or single-node computational tasks in a shorter elapsed time than Big Red II.

Table 12. Disciplines and sub-disciplines represented among users of Big Red II and Karst (rows and columns are not additive because the totals are unique disciplines and sub-disciplines, and there are several users)

System	Disciplines & Sub-disciplines represented among users		
	IUPUI	IUB	Total
Big Red II	68	141	159
Karst	117	164	214
Total	136	201	243

During the first half of 2015, CPU time devoted to parallel jobs on 34 processors (17 nodes) or more on Big Red II was 65% overall. The decrease in serial jobs running on Big Red II – seen in the early part of calendar 2015 – is consistent with a belief that part of the rise in serial jobs on Big Red II in late 2014 had to do with demand for this sort of computational task exceeding Quarry's capacity. Such jobs decreased this calendar year thanks to Karst's overall higher capacity.

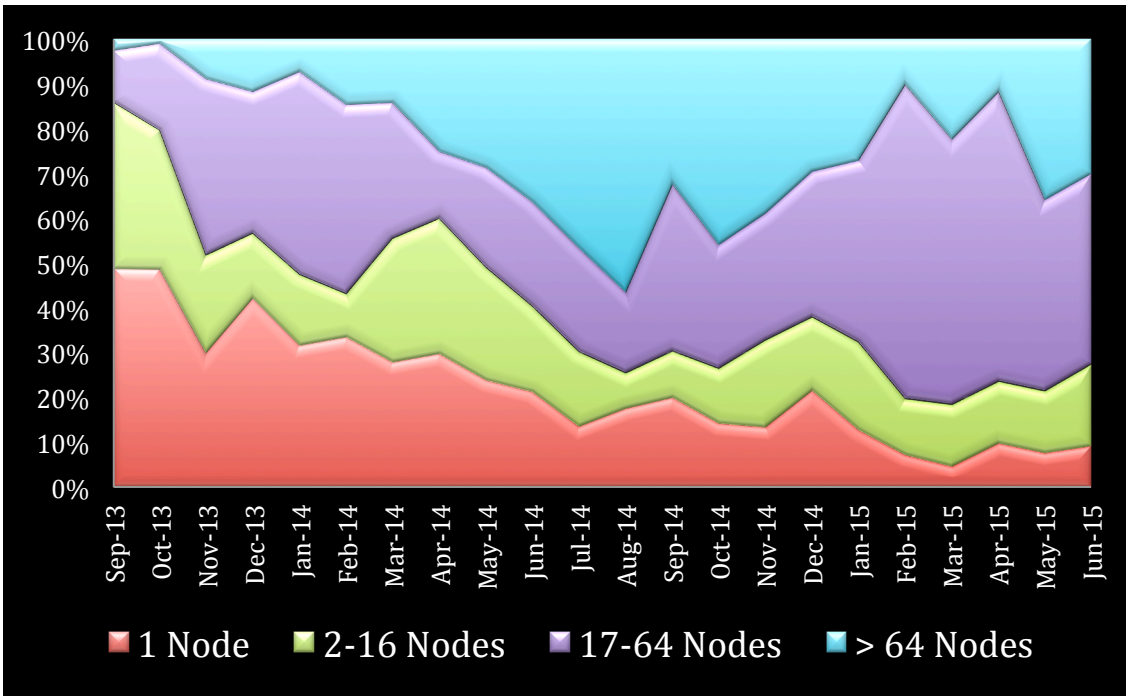


Figure 10. Percentage of Big Red II CPU utilization by job size (each node is two processors – either two CPUs or one CPU and one GPU)

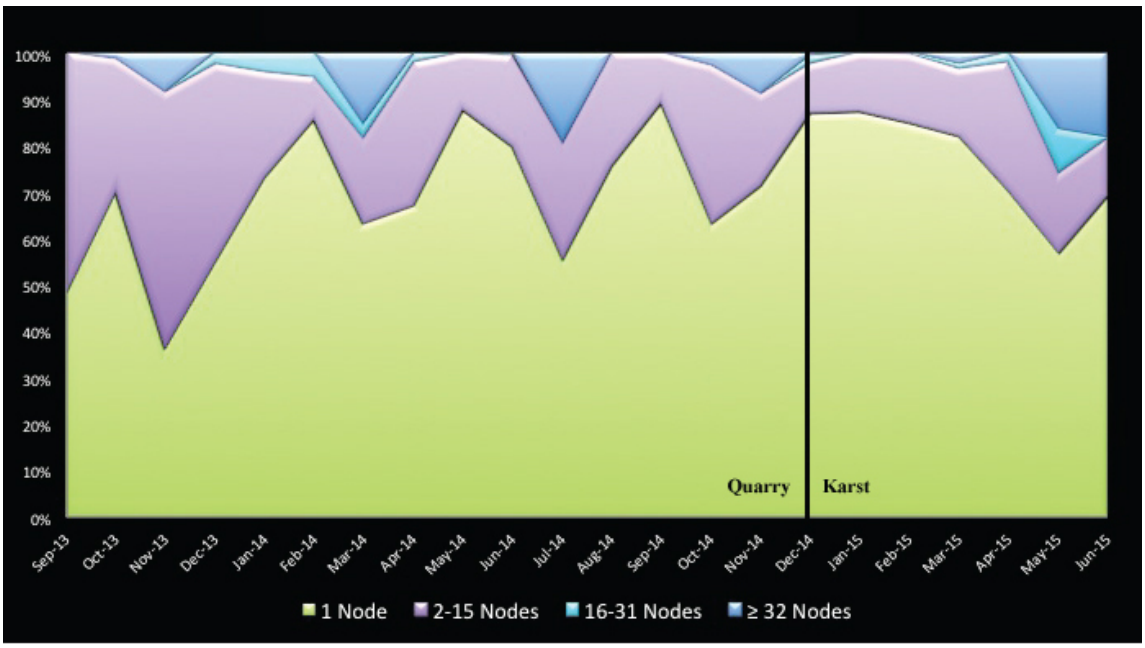


Figure 11 Quarry/Karst usage since 2013 by degree of parallelism. Total Quarry nodes: 270, for a total of 22.25 TFLOPS. Total Karst nodes: 263, for a total of 87.5 TFLOPS.

Figure 10 is similar to **Figure 11** and shows usage of the systems intended primarily for high-throughput and single-node workloads – the new Karst system and its predecessor Quarry. From January to June 2015, 74% of the Karst utilization was devoted to single-node jobs.

Overall, Research Technologies delivered a tremendous number of computational resources.

Table 13. Research Technologies delivery of resources to the IU research community – counting local cyberinfrastructure and use of national cyberinfrastructure supported by RT

System	Jobs	CPU hours
Big Red II	319,106	128,239,686
Karst	424,329	17,025,544
Mason	70,648	5,961,997
Quarry	3,814,570	5,200,548
XSEDE use by IU researchers	1,277	195,664
Open Science Grid use by IU researchers	25,808,916	26,619,180
Total	30,438,846	183,242,619

Highlight: Survey helps lead the future of science gateways

The number of users accessing resources via science gateways now surpasses the number of users accessing resources locally, according to the Extreme Science and Engineering Discovery Environment (XSEDE) and the National Energy Research Scientific Computing Center.

Science gateways are user-friendly interfaces to advanced technologies that support science, engineering, research, and education. Frequently implemented as web and mobile applications, they provide access to community resources like software, data, collaboration tools, instrumentation, and high-performance computing.

The IU Science Gateway Group (SGG) and its partners administered a large-scale survey—possibly the largest of its kind—to measure the extent of reliance on gateways, and gain insights into useful services and support for builders and users. The survey went out to nearly 29,000 principal investigators, senior administrators, and people with gateway affiliations. The nearly 5,000 respondents reflected a range of expertise and geography. (For more on the survey, see: http://onlinelibrary.wiley.com/doi/10.1002/cpe.3526/full)

Survey results indicate that gateways are an active part of the science and engineering research and education landscape. Many scientists and educators depend on web-based applications to access specialized resources, particularly for computation and data access and analysis. The survey also identified developmental and operational gaps that offer room for growth. These include the need for incubator-like services to help gateways find their right communities, as well as embedded expertise from experienced staff during gateway development efforts.

Highlight: IU Science Gateway Group

SGG provides national leadership for the science gateway community. Activities include the development of Apache Airavata, a top level Apache Software Foundation project; the deployment of the NSF-funded Science Gateway Platform as a Service (SciGaP.org), a hosted service platform that is based on Apache Airavata; and leadership of the XSEDE science gateway program.

Through the tools and gateways developed by SGG, more than 25 publications have been supported (SEAGrid, UltraScan science gateway led by B. Demeler at University of Texas Health Science Center at San Antonio).

7.1.1.3. Evolve IU's approaches to data and systems in ways that enable best practices across the university

- Indiana University has long been a leader in the creation and deployment of systems for data management. In 1999 then-Vice President McRobbie made the protection of IU's data assets a university priority when IU first established the highly secure tape storage system now known as the Scholarly Data Archive (SDA). The SDA enables research workflows, stores state GIS data, and serves as the permanent archive for the Media Digitization and Preservation Initiative.
- Key highlights in the establishment of IU's leadership in data-centric computing were two NSF Major Research Infrastructure awards: the first in in 2001 for the AVIDD project (Analysis and Visualization of Instrument-Driven Data) with then-VP McRobbie as the Principal Investigator, and the second in 2005 for the Data Capacitor advanced data management system with Craig Stewart as the Principal Investigator. Deployed in 2013, IU's Data Capacitor II system has extended the capability of the original with a 5x increase in bandwidth while increasing the capacity tenfold. DC II provides high-speed short term scratch space and mid-term project space for IU's HPC users.
- Table 14 below presents the RT data storage systems, purpose, and PB of storage. Figure 9 shows good citizenry of SDA users removing large amounts of data that was no longer needed, followed by continued steady growth.
- Figure 1 shows the dramatic increase of data stored on Data Capacitor II since it was put into service in 2013.

Table 14. Research Technologies data storage systems

Name	File system	Purpose	Disk (PB) total (unformatted)	Disk (PB) usable (formatted)	Tape (PB)
Geode	GPFS	Main storage system for home directories and critical files stored on disk by IU researchers	1.2	0.6 (replicated)	NA
Data Capacitor II / DC-WAN	Lustre	High speed, typically short term data storage for research data	6.47	4.85	NA
Scholarly Data Archive	HPSS	Reliable tape storage, with copies of data kept by default at IUPUI and IUB to ensure security of data	1.8	1.5	18
Totals			**9.47**	**6.95**	**18**

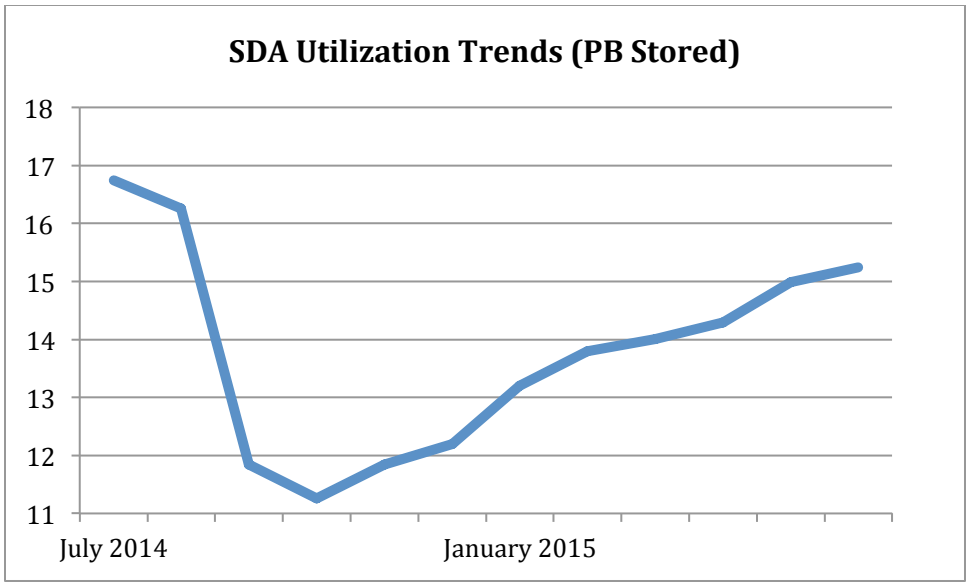


Figure 12. Utilization trends for the Scholarly Data Archive showing significant user removal of data that was no longer needed, and continued steady growth.

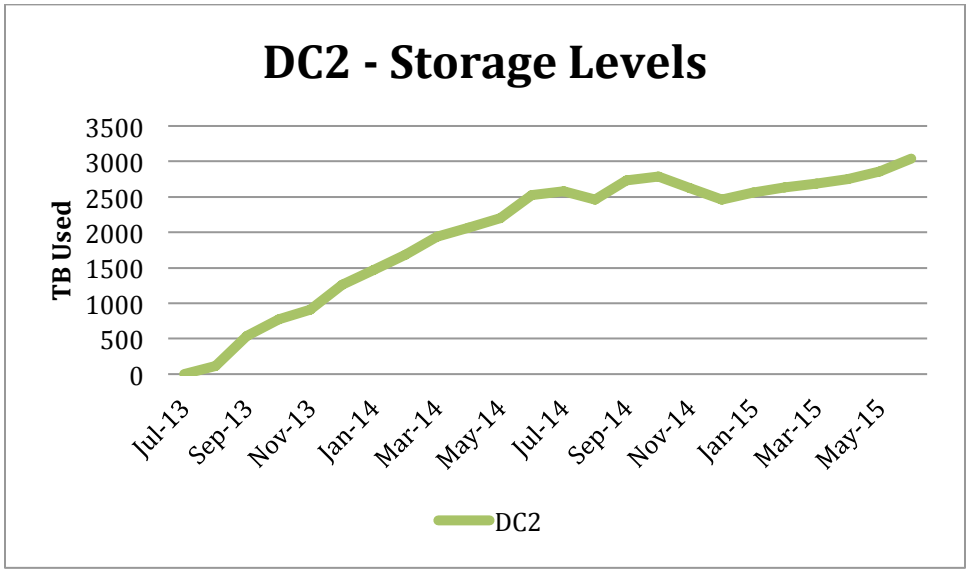


Figure 13. Data Capacitor II increased usage since its deployment in 2013.

Increasingly, "condominium computing" is being used as a means by which to better utilize computing resources. At IU, researchers (individuals, labs, departments, or schools) may purchase computational nodes and house them within the IU Bloomington Data center rather than in a separate facility (office, lab, etc.). The nodes are available to the researchers within seconds; however, the burden of securing and managing the cluster is taken on by Research Technologies. Nodes can be used by others in the IU community when not in use by the researchers, they become available to others in the IU community. Because of the benefits to the IU community, UITS hosts these nodes without charging colocation, network, or power usage fees except in cases where researchers need a non-standard configuration or if the nodes are dedicated exclusively to the researcher. One additional research group entered into a Karst condo node agreement in FY2015 adding to the four agreements that were carried over from Quarry.

Where an agreement spans a system-wide upgrade researchers will unusually benefit to a free upgrade on their condo node for the remaining term of their agreement.

7.1.1.4. Align technology-based library and information services with physical library spaces and services

PTI supports a number of online information systems used at IU, throughout the academic community as a whole, and by the citizenry of the state of Indiana.

- HathiTrust Research Center. HTRC is the research arm of HathiTrust. It is a partnership between IU Libraries, PTI, and School of Informatics and Computing at IU, and the University of Illinois, Urbana-Champaign (UIUC) Libraries and Graduate School of Library and Information Science."[12] HTRC's current focus is providing tools for analysis of large-scale texts – hundreds of thousands of documents comprising millions of pages of text. HTRC provides a portal from which researchers can operate text analysis applications using the some 3 million HathiTrust volumes that are in the public domain. HTRC also offers an API into the HTRC tools, so researchers can create their own text analysis tools.
- IUScholarWorks. IUScholarWorks (scholarworks.iu.edu), operated by the IU Libraries, serves as IU's primary persistent digital repository. It is based on a front end that runs under the open source DSpace software. Its back end is the Scholarly Data Archive. IUScholarWorks is the tool IU is using to ensure that the wealth of data and information collected and generated by the IU community remains accessible to and useful for generations to come.
- **Indiana CTSI HUB.** This is the online portal for the Indiana Clinical and Translational Science Institute, and one of the most widely used data access resources within the IU clinical and translational research community. It is described in detail in Section 7.
- SEAGrid. The Science and Engineering Applications Grid (SEAGrid.org), formerly known as GridChem, is a science gateway that provides access to computational chemistry, material science, and engineering applications on IU and XSEDE computing infrastructure. SEAGrid is operated by the RT Science Gateway Group and is a tenant in the Apache Airavata-based SciGaP hosted services. During the reporting period, SEAGrid led to at least 18 scientific publications by researchers from around the world. During the 2014-2015 reporting period, SEAGrid was the second most heavily used XSEDE gateway by numbers of jobs run and computing hours used.
- **Indiana Spatial Data Portal for GIS data**. The ISDP provides access to more than 30 terabytes of Indiana geospatial data. The ISDP provides a variety of geospatial data sets for the state, including the most recent orthophotography and lidar data commissioned by the state. During the 2014-2015 reporting period the ISDP website had over 5,300 visitors. Through the ISDP multi-file download interface over 35,000 files were downloaded in more than 5,700 sessions. The total volume of data downloaded was over 1.78 TB.
- ODI-PPA. The ODI Pipeline, Portal, and Archive (ODI-PPA) is a comprehensive web-based solution that provides astronomers and WIYN Consortium members (University of Wisconsin, Indiana University, National Optical Astronomy Observatory, and the University of Missouri) with access to the One Degree Imager (ODI). The modern user interface acts as a single data access point coupled with rich computational and visualization capabilities. It supports scientists in handling complex data sets, while enhancing WIYN's scientific productivity. Most of ODI-

[12] HathiTrust, "What is HathiTrust?"

PPA is powered by software written by (or integrated by) RT staff, and running on RT hardware including SDA. ODI-PPA has also enabled offshoot Scalable Compute Archive (SCA) projects powered by the Trident microservice and software suite, including EMC-SCA and GCS-SCA.

- **Cyberinfrastructure Gateway**. The Indiana University Cyberinfrastructure Gateway (CI Gateway) is an online portal designed to centralize information about and access to IU's advanced scholarly and artistic CI. The gateway allows users to find information on current queues, get help, see outages, find information on available software, and transfer and manage data. During the reporting period, the CI Gateway supported over 5,800 sessions, including 468 unique sessions lasting at least 10 minutes and over 1,100 frequently returning users (users who came to the gateway at least 9 times).
- **QuakeSim/GeoGateway**. The QuakeSim science gateway (renamed GeoGateway) is the product of a long-standing collaboration between researchers at NASA Jet Propulsion Laboratory and PTI/RT. The portal gives users simple access to sophisticated InSAR datasets, GPS time series data, and forward/inversion modeling tools for comparing earthquake fault models. GeoGateway delivers over 3 TB of UAVSAR data (synthetic aperture radar data collected by aircraft) to NASA researchers. Web services are hosted on Quarry gateway hosting resources and use Geode to host data.
- **UltraScan.** The UltraScan science gateway (PI Dr. Borries Demeler, University of Texas Health Science Center San Antonio) allows biophysicists to perform data analysis on analytical ultracentrifugation experiments, uncovering properties of molecules in solution. Through a collaboration with PTI/RT, this data analysis is performed on campus resources, on national cyberinfrastructure (XSEDE), and at international supercomputing centers in Germany. UltraScan is supported by the Apache Airavata-based SciGaP hosted services operated by the RT Science Gateway Group.
- **SPLInter.** The Structural Protein Ligand Interactome is a computational drug design and discovery resource for ranking molecules docked to the human proteome. The portal contains the DOPIN (Docked Proteome Interaction Network) database, which contains millions of pre-docked and pre-scored complexes from thousands of targets from the human proteome and thousands of drug-like small molecules from the NCI diversity set and other sources. SPLInter uses the Open Science Grid for docking simulations and presents visualization, scoring, and ordering information via a web portal.
- **Galaxy portal at IU**. The National Center for Genome Analysis Support provides three web-based portals that feature easy-to-use interfaces for genomics researchers to create and execute their own workflows on NCGAS systems. Using the Galaxy web portal environment, NCGAS has created Galaxy portals for IU investigators, NSF-funded life science researchers across the nation, and the Penguin On Demand system for federally-funded investigators. These provide access to the full suite of genome assembly, annotation, alignment, and other applications – as well as file transfer and transformation utilities for building genome science workflows.

7.1.1.5. Support leadership role in sustainable and energy-efficient computing

Research Technologies has been involved with the Standard Performance Evaluation Corporation for over a decade, and has contributed development effort towards High Performance Commuting benchmarks. When SPEC started to support measuring energy consumption as part of their single node benchmarks, RT submitted benchmark results for the SPEC OpenMP benchmark on the Quarry cluster. In addition, RT contributed energy measurements for running the benchmark on a regular server and within a virtualized environment. This allows for comparing not just the performance hit that users will take by running

virtualized applications, but also how much additional energy a virtualized environment consumes compared to a native execution.

7.1.2. Bicentennial Priority Six: Indiana University and IU Health, including Riley Hospital for Children, will strategically invest in world-class research and training in selected areas of the health sciences – with emphasis on cancer, cardiovascular disease, and the neurosciences – through targeted hiring, collaboration, and infrastructure investments which have the potential to be translated into new and improved treatments, cures, and procedures. …

Bicentennial plan action items to which PTI has and will contribute include:

- IUSM, and where relevant the other IU clinical schools, will continue to build research capacity in selected areas – with special focus on research in population health, cancer, cardiovascular disease, neurodegenerative diseases, and pediatrics through the Riley Children's Hospital and Foundation – in order to achieve preeminence in these areas, and to generate increased external research funding from the NIH, DOD, Patient Centered Outcomes Research Institute (PCORI), and other external sources.
- IU will invest in the infrastructure to foster collaboration in research and educational programs among the clinical schools and other academic units, leveraging the Indiana Clinical and Translational Sciences Institute (CTSI) wherever possible, in order to increase opportunities for students and researchers.

Research capacity built through cyberinfrastructure investments and services has been described in numerical terms above. Key highlights of RT and NCGAS support for health sciences research include:

- AVL staff assisted Dr. Ahmed Ghoneima with the creation of 3D printed tooth models for teaching and research. Dr. Ghoneima provided example tooth geometry extracted from CBCT scans. AVL then built programmatic scripts that enable IU School of Dentistry faculty and students to create their own 3D printable tooth models.
- AVL staff assisted IUSD prosthodontic student Travis Bellicchi with the design and fabrication of a 3D printed prosthetic ear, mold, and surgical guide. The goal of this project was to explore how each of these might improve the currently cumbersome handmade process of per-patient prosthetic creation and placement. The samples were fabricated at the IUPUI Library 3D Printing Lab and at Shapeways.com.
- Dr. Judi Chin, a professor in the IU School of Dentistry, continued to make good use of their IQ-Force stations. IUSD uses a combination of three IQ-Force stations and simulation software to help students practice giving injections to virtual patients before giving injections to classmates.
- AVL continues its support of the Collaborative Initiative in Fetal Alcohol Spectrum Disorders (CIFASD) project. The Lab deployed a new scanner system to Rapid City, SD and led the resolution of a variety of hardware problems (often in international locations). See research highlight following Table 15.

Metrics identified in the IU Bicentennial Strategic Plan include the following

- Amount and research funding from the National Institutes of Health (NIH) see Figure 5.

Computing centers tend to be good at counting things like terabytes used and teraflops of computing power consumed. Operational metrics – like number of databases supported, number of records in databases, and number of collaborations and studies enabled – are often as, or more, important to

researchers in the IU School of Medicine. In this section, we present such metrics for the operational services provided by Research Technologies to IUSM researchers. These services are delivered primarily via the Advanced Biomedical Information Technology Core (ABITC), a management unit of Research Technologies. ABITC was the first service outside of the school certified as an official IUSM core.

Table 15. Usage metrics for data resources managed and supported by ABITC and Research Technologies

Service	Number of records			Services delivered
	FY 2013	FY 2014	FY2015	Description
Data repository for Collaborative Initiative on Fetal Alcohol Spectrum Disorder	3,420	3,732	4,017	Number of distinct subjects (people)
	34,751	39,275	43199	Total number of database entries
	412	524	591	Brain images stored in CIFASD Imaging Core data repository
Data repository for National Gene Vector Biorepository and Coordinating Center	107,576	111,550	124, 588	Number of database records
Indiana CTSI HUB	4,729	6,070	7,381	Number of login (accounts) on the Indiana CTSI Hub
REDCap	681	935	1,141	New projects using REDCap initiated by researchers
	1,362	2,297	3,438	Total projects using REDCap since ABITC assumed responsibility for REDCap in 2010
CTSI Grants Management System	28	25	31	Grant competitions managed
	106	105	54	Proposals/submissions awarded
	96	121	152	Grant competitions managed since inception in 2009
Total Records	**153,161**	**164,634**	**184,592**	

Highlight: Using 3D imaging to identify prenatal alcohol exposure

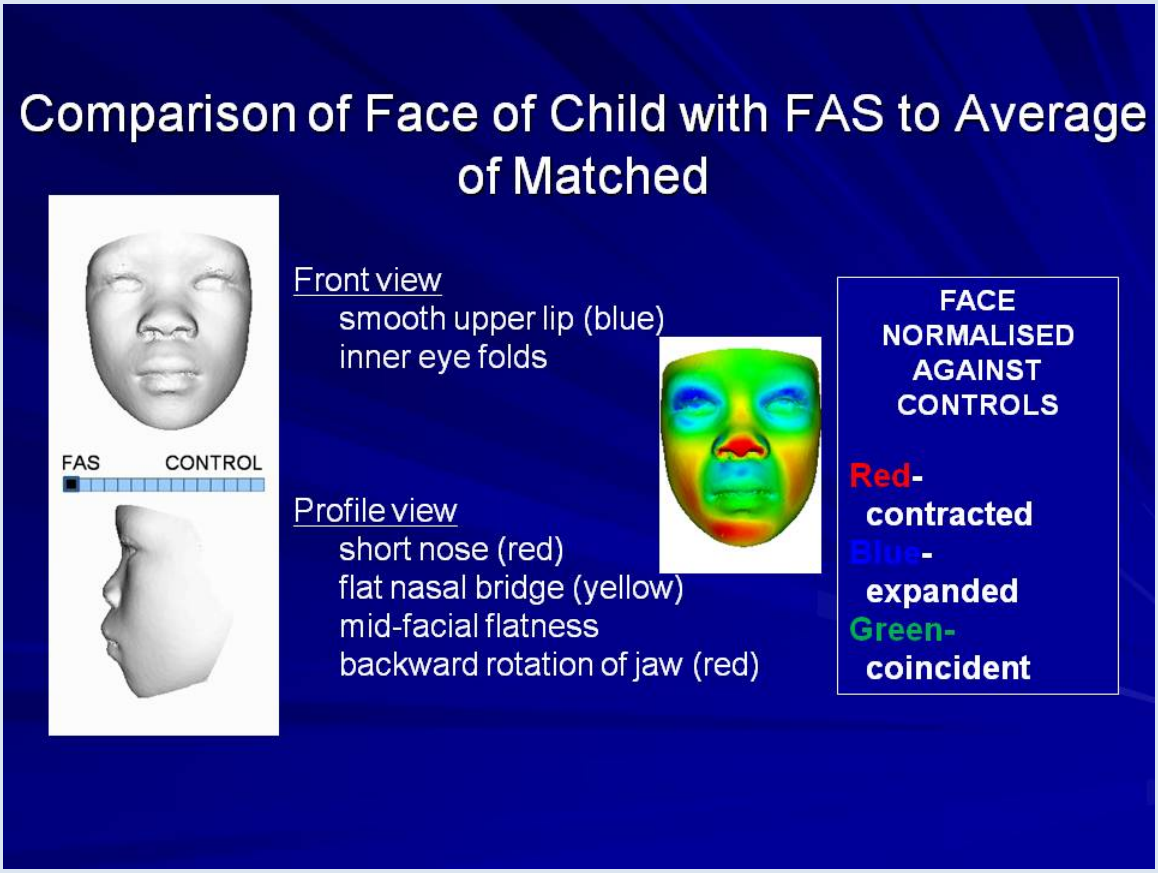


Image courtesy http://cifasd.org/research/#Foroud-Hammond

The Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) seeks cross-cultural assessments of FASD, in order to improve clinical screening tools that provide early identification of children exposed to alcohol prenatally. The goal is to create an international collaboration of multi-disciplinary researchers using cutting-edge techniques and data to further the field of study.

Principal Investigators Tatiana Foroud and Peter Hammond are leading a CIFASD project focused on the identification of the facial features of FASD through 3D imaging. With the aid of 3D surface scanning technologies, they hope to better understand how the face changes and how those changes correlate with other conditions related to prenatal alcohol exposure.

The UITS Advanced Visualization Lab (AVL) provides research support for this 3D facial imaging, alleviating technical challenges related to data acquisition. This support includes the deployment and technical support of six portable 3D facial scanning systems to the US and international locations like South Africa and the Ukraine.

In the past year, the AVL remotely assisted with equipment malfunctions and replacement parts in Khmelnytskyi and Rivne, Ukraine. In addition, the AVL deployed a new system to Rapid City, South Dakota to further increase cross-cultural data samples. Custom processing programs written by AVL staff continue simplify the process of creating various 3D file formats for researchers in the United Kingdom and around the globe.

Highlight: AVL partnering to make Cuban Center a first-of-its-kind broadcasting facility

In June 2015, IU announced the creation of the Mark Cuban Center for Sports Media and Technology, established via a $5M gift from IU alumnus Mark Cuban. The Advanced Visualization Lab (AVL) has a long and successful history of innovating with virtual reality and advanced media technologies that benefit IU researchers. Working with IU Athletics, the AVL and the Cuban Center will continue to push the boundaries of immersive and engaging experiences.

The Cuban Center will enable the use of cutting-edge tools and techniques that feature advanced video and broadcasting, virtual studio, and related technologies such as virtual and mixed reality. Improving the fan experience will be a key focus. IU basketball and football will be the earliest adopters, and students will play an integral role. Through center-sponsored courses, independent projects, and internships, IU will graduate some of the most tech-savvy and capable students in the nation.

AVL worked closely with IU Athletics to prepare for the center's opening, showcasing numerous technologies. AVL also co-organized and facilitated a weekend hack-a-thon that invited developers and artists to join together to create a novel fan experience. Other IU collaborators on the center include the Media School, IU Radio TV Services, and the School of Informatics and Computing.

7.1.3. BICENTENNIAL PRIORITY EIGHT: TOWARDS A CULTURE OF BUILDING AND MAKING

Bicentennial Priority Eight: Indiana University will explore and pursue the feasibility of establishing new programs in design and engineering on the IU Bloomington campus and technology programs on the regional campuses to meet regional needs.

- **AVL installs an IQ-Wall in the Well's Library Scholar Commons.** The Scholars Commons IQ-Wall features approximately 15 million pixels arranged in a 4x4 tiled grid. Like all IQ-Walls, it runs Windows and is accessible to all IU faculty, staff, and students via ADS login. Additionally, this IQ-Wall is the first to offer stereoscopic 3D viewing, which complements the capabilities of other advanced displays on the campus.
- **Research Technologies expands the availability of spherical displays.** UITS deployed a new spherical display technology called a Puffersphere to complement the existing Science on a Sphere display. The Puffersphere is a smaller display that can be easily moved around IU campuses or buildings, and is the first spherical display at IU to offer a multi-touch interface. Its SC14 conference debut was a success, and its current setup at IUPUI has generated much interest from the Informatics community. Data and software workflows can be shared between the Science on a Sphere and the Puffersphere.

Highlight: August 2014 Makevention

Makevention is where maker groups in Bloomington area communities come together to share the do-it-yourself spirit with each other and the community. These makers encompass a broad range of fields, including tech enthusiasts, artists, educators, crafters, hobbyists, and tinkerers. Sponsored in part by IU Research Technologies, Makevention at the Bloomington Convention Center attracted 600 people with 27 groups exhibiting. Bloominglabs, a local hackerspace, helped organize the event. Jenett Tillotson and Nathan Heald from RT play a leading role in supporting Bloominglabs and organizing events such as Makevention

This event draws together the local community of makers of all ages. It encourages family participation in the art and science of making familiar items like soap, hats, and jigsaw puzzles. Parents can learn how to pick locks, become ham radio operators, or debug sensors. Children can build or play ball with a robot, make a hat from old clothing, make soap, or try to crack a word challenge puzzle. Everyone is having fun with these activities while also learning about science, engineering, or building through hands-on activities – STEM learning is one of the main outcomes of this event.

Highlight: RT supports Herron School makerspace

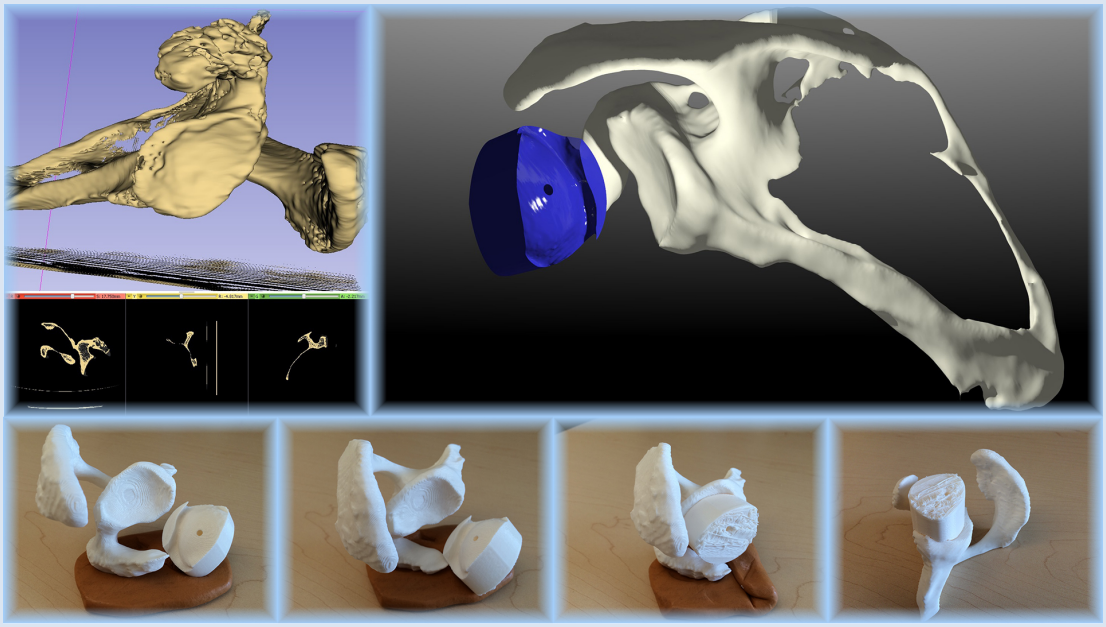


Figure 14. This image highlights the stages of converting volumetric computerized tomography (CT) data into a watertight surface mesh for a custom fitted 3D printed surgical guide for shoulder replacement surgery.

Art, design, and technology are evolving to become integrated parts of the creative process, especially at the Think It Make It Lab at the IUPUI Herron School of Art and Design. The Lab is a hands-on 'makerspace' with cutting-edge digital prototyping equipment. It provides current and budding artists, technologists, and engineers a collaborative environment where experimentation and exploration are encouraged and embraced.

The first of its kind at Indiana University, the Lab directly supports growing interest in maker culture and interdisciplinary environments for research, education, and engagement. Having an on-campus fabrication center facilitates hands-on learning and affords quicker turnaround time for prototyping -- meaning students will gain skills that immediately transfer to industry careers.

Lab equipment will consist of computers, cameras, 3D scanners, and fabrication equipment like 3D printers, CNC (computer numeric control) routers, milling machines, and laser and plasma cutters. Key partners include the IU School of Medicine, the Fairbanks School of Public Health, the School of Informatics and Computing, the Purdue School of Engineering and Technology, and University Information Technology Services (UITS). Several courses and projects have already been established.

For more than a decade, the university has relied on external equipment and vendors. The UITS Advanced Visualization Lab (AVL) is proud to have partnered on proposal development and technology solutions to help change this situation. As the Lab takes shape, AVL looks forward to offering advanced consulting services and support related to 3D scanning and digital fabrication projects. The Think It Make It Lab will be an evolving space that continuously opens new possibilities and applications.

8. Appendix 1: Listing of PTI and Research Technologies Facilities and Services

1. Physical facilities

IU's cyberinfrastructure leverages the university's unusual arrangement of two major research campuses separated by 50 miles and connected by university-owned optical networks. This creates tremendous resilience in case of natural or man-made disaster, and provides an outstanding testbed for development of grid and distributed computing innovations. **Table F. 1** summarizes IU's data center facilities. IU has at present a net of 1 MW of power available to support new and expanded research cyberinfrastructure.

	Machine room total ft²	Avail. ft²	Power total	Net power avail.	Cooling capacity total (tons)	Cooling capacity avail. (tons)
ICTC	8,300	1,400	600 kW	70 kW	290	150
IUB Data Center	30,000	15,000	2.5 MW	1 MW	2750	550

Table F. 1. Summary of physical facilities at Indiana University

1.1. IU Bloomington Data Center

The IU Bloomington Data Center (http://it.iu.edu/datacenter/) provides a highly secure and green environment for IU's largest computational and storage systems. The facility is secured with card-key access, biometric authentication, and 24x7x365 video surveillance. Only staff with systems or network administration privileges have access to the machine room. Fire suppression is provided by a double-interlock system accompanied by a Very Early Smoke Detection Apparatus (VESDA). Three circuits feed the new Data Center, travelling redundant physical paths from two different substations. Any two circuits can fully power the building.

1.2. Informatics & Communications Technology Complex

The Informatics and Communications Technology Complex (ICTC) houses IU's Data Center in Indianapolis. The ICTC is secured with card-key access and 24x7x365 video surveillance. Fire suppression is provided by a dry-pipe, pre-action sprinkler system in accordance with university risk management policy. The electrical design for the ICTC includes UPS service and generator backup for the entire facility.

1.3. Cyberinfrastructure Building

The Cyberinfrastructure Building (CIB) on the Bloomington campus opened in August 2011. Located in Technology Park East along with the IU Bloomington Data Center and the Innovation Center, the CIB houses University Information Technology Services (UITS) staff. Previously, staff were located in multiple buildings across campus. The CIB brings UITS staff together to work more efficiently and effectively than ever before.

1.4. Sustainability of physical facilities

IU Bloomington's Data Center is significantly more efficient than former facilities. The walls are made of 9,000 cubic yards of poured concrete with several sustainability features: longevity; thermal mass that decreases heating and cooling needs; recycled content; minimal waste; and regional production. The single-story facility is surrounded by an earthen berm, offering added insulation and protection from weather events, including tornadoes up to and including category 5. The walls and berm together reduce

the impact of temperature extremes and help lower heating and cooling costs and energy requirements. The mechanical equipment includes air- and water-side economizers to improve the cooling efficiency. Construction took into account federal guidance regarding sustainability and green business practices. IU achieved LEED Gold certification for the CIB and LEED Silver certification for the Innovation Center.

2. Overall structure and support of IU's advanced research cyberinfrastructure

PTI staff support all local, national, and international users of IU's research cyberinfrastructure as part of their ongoing operational responsibilities. This includes support for high performance computing systems, data storage systems, and visualization systems. Periodically, external grants and contracts help fund this support when the contract or grant determines terms of or access to such services. Otherwise, this support is made possible by IU general funds.

Online support is provided 24x7x365 by IU's award-winning Knowledge Base (kb.iu.edu). Support for security and emergency situations is provided by telephone 24x7x365 via staff at the IU GlobalNOC. In-depth support is available via email, telephone, and in-person meetings.

3. High performance computing (HPC) systems

IU has the following production high-performance computing systems.

- *Big Red II.* Big Red II is a 12-cabinet, 1-petaFLOP supercomputer from Cray Inc., installed in April 2013. Big Red II has an aggregate peak theoretical capability of just over a petaFLOP, and an aggregate RAM of 43.6 TB. Big Red II consists of 1,020 nodes total: 344 XE6 nodes, each with two 2.5 GHz AMD Abu Dhabi processors and 64 GB of memory; and 676 XK6 nodes, each with one 2.3 GHz AMD Interlagos processor and one NVIDIA K20 accelerator with 32 GB of system memory and 5 GB of GPU memory. The nodes are interconnected in a 3D Torus using Cray's Gemini interconnect, which provides 20 GB/s of bandwidth per node. This system has more bandwidth to high performance file systems like the Data Capacitor than ever before, as they connect via a low-latency InfiniBand network that provides an aggregate throughput to storage of 48 GB/s. Big Red II includes 180 TB of local spinning disk storage.
- *Karst.* Karst is a new, high-throughput cluster that includes condominium services for research groups. Karst has an aggregate peak theoretical capability of 91.5 teraFLOPS, and an aggregate RAM of 11 TB. Karst consists of 275 nodes total. Of these, three larger-memory nodes are dedicated to supporting NIH users. Karst has a 10-gigabit Ethernet interconnect. Karst includes 450 TB of local spinning disk storage. Karst features standard Linux nodes – grouping in a condominium style means nodes owned by a particular user are available for IU community use when not needed by the owner.
- *Quarry Gateway Hosting system.* The Quarry Gateway Web Services Hosting resource at Indiana University consists of multiple Intel-based HP systems geographically distributed for failover in Indianapolis and Bloomington, IN. Currently there are five HP DL160/360 front-end systems at both sites, all configured with Intel processors, 96-128 GB of RAM, and a 10-gigabit-Ethernet adapter. The front-end systems host the kernel-based virtual machines (KVMs). Virtual machine (VM) block storage is provided by three HP servers at each site, configured with an Intel processor, 12-32 GB of RAM, a 10-gigabit-Ethernet adapter, and a RAID controller attached to an HP storage array or internal storage. A standard VM consists of 1 virtual CPU, 4 GB of memory, and 10 GB of persistent local storage. Service owners are granted root access to their virtual machines. The Data Capacitor WAN file system can also be mounted for larger project and scratch space. The host operating system is Ubuntu. The supported virtual machine operating systems are Red Hat Enterprise Linux, CentOS, Ubuntu, and Debian Linux. The Quarry Gateway Hosting System has an aggregate peak theoretical capacity of 1 teraFLOPS and 1 TB of RAM, and includes 264 TB of Ceph block storage for VMs.
- *Mason.* Mason is an HP distributed, shared-memory cluster with 576 processor cores, 9 TB total memory capacity, and a peak theoretical capability of 4 TFLOPS. The compute nodes consist of 18

DL580 G7 servers, each with four 8-core Intel Xeon L7555 processors, 512 GB of memory, and a PCIe 10Gb-Ethernet adapter for high-bandwidth data transfer. The cluster includes 18 TB of local spinning disk.

- *US ATLAS Midwest Tier 2 Center* (http://mwt2.usatlasfacility.org/). The IU portion of the MWT2 facility is a heterogeneous cluster of 20 Dell 1950 servers, 56 Dell R410 servers, and 80 white-box servers, connected by a 1.0 Gbps network. This heterogeneous cluster has a total of 1,312 processor cores, 4.0 TB total memory capacity, and a peak theoretical capability of 13.6 TFLOPS. The Dell and HP compute nodes include a mix of 4-core Quad Core Xeon E5440 Processors and 6-core Intel Xeon CPU X5660 processors, with between 2 and 4 GB of memory per core. The white-box servers include a mix of Dual- and Quad-Core AMD Opteron processors. The IU MWT2 center includes 156 TB of local spinning disk storage.
- *Research Database Complex.* The Research Database Complex (RDC) is dedicated to research-related Oracle and MySQL databases and data-intensive applications based on relational databases and web applications that rely on database back ends. RDC has an aggregate peak theoretical capability of 0.3 teraFLOPS, and an aggregate RAM of 0.3 TB. RDC consists of 5 nodes total. The database-serving component of RDC consists of 4 HP DL160 servers, each with dual Intel E5620 processors, two 72 GB SAS disks, and 72 GB of memory. The RDC web serving environment is a Dell 2950 with a Quad-core Intel Xeon processor and 8 GB of memory. The RDC has a 10-gigabit Ethernet interconnect. The RDC has 144 TB of SAN-attached storage for database hosting.

Name	Architecture	TFLOPS	Total RAM (TB)	Local disk (TB)
Big Red II	Cray XE6/XK6 (AMD x86-64 and NVIDIA K20)	1000.4	43.6	180
Karst	IBM NeXtScale nx360 cluster	91.5	11	450
Quarry	HP DL160/360/180/380 cluster	1.0	1	264
Mason	HP DL360/580 cluster	4.0	9	18
RDC	HP DL160 database servers, Dell 2950 Web server	0.3	0.3	144
Totals		**1097.2**	**64.9**	**1056**

Table F. 2. Summary of computational resources at Indiana University

4. Data storage systems

In addition to the locally-attached storage listed above, IU has three major disk-based file systems and one archival storage system that serve local and remote users. These include:

- *Geode.* Geode is a new disk-based filesystem with a capacity of 1.2 PB (600 TB usable due to replication) that allows for group collaboration via file sharing. Users have a highly flexible system for granting access to files, and the underlying GPFS technology used for the system replicates all data to both IU Bloomington and IUPUI for a highly available system architecture. Researchers can request dedicated project space for each project requiring dedicated storage and collaboration. Users can access files from their desktops (CIFS) and via SFTP. This system is part of the replacement for the Research File System (RFS) based upon OpenAFS and the previous HPC home directory solution, which had been served by a NetApp NAS. Furthermore, Geode is providing Condo storage, which allows research departments to purchase large allocations of storage (beginning at 100 TB) to store data for projects across their departments.

- *The IU Data Capacitor II.* The Data Capacitor II is a high-speed/high-bandwidth Lustre storage system that serves the high performance computing systems at IU Bloomington. Installed in February 2013, DCII includes a 5 PB Lustre file system (4 PB usable) from Data Direct Networks (DDN), with an aggregate 48 GB/s of data I/O capability. DCII includes 16 Lustre object storage servers, two Lustre metadata servers, and eight Lustre routers, all connected via full-data-rate (FDR) InfiniBand to two DDN SFA12000 storage controllers. The Lustre routers also have 10-gigabit Ethernet connections to allow systems without InfiniBand to access the system. The two metadata servers are connected to a DDN SFA6620 storage controller.
- *The Data Capacitor Wide Area Network (DC-WAN)* file system is a high-speed/high-bandwidth Lustre storage system for research computing that serves all IU campuses and other sites throughout the country, primarily by wide area network (remote) Lustre file system mounts. DC-WAN has a total formatted capacity of 1.1 PB, with 40 Gbps maximum I/O. DC-WAN consists of Dell 2950 servers running the Lustre file system. DC-WAN has four servers equipped with 10-gigabit Ethernet cards for object storage, and two that use Gigabit Ethernet for Lustre metadata. DC-WAN can map remote users to local users, allowing machines with heterogeneous namespaces to communicate seamlessly. DC-WAN currently serves a legacy role within XSEDE for 40 XSEDE project allocations that require DC-WAN's capabilities for file storage and long distance accessibility. These are projects that have not found other XSEDE services that meet their needs. IU provides wide area file system connections for over 10 collaborators and facilities.
- *IU's Scholarly Data Archive (SDA).* SDA uses High Performance Storage System (HPSS) software to make available to IU researchers a total storage capacity exceeding 18 PB. Data is written to a fast, front-end disk cache and migrated over time to IBM TS3500 tape libraries on the Indianapolis and Bloomington campuses. Data written to IU's HPSS system are copied simultaneously to both locations, providing highly reliable disaster protection. Users can access data over the network from central research systems or from personal workstations, using SFTP, HSI/Htar, CIFS, and HTTP. The default allowance is 50 TB of mirrored data, with additional space provided upon request. SDA stores and provides access to data for the IUScholarWorks Repository (http://scholarworks.iu.edu), a document and data archiving system created using DSpace software.

Name	File system	Disk PB unformatted	Disk (PB) usable (formatted)	Tape (PB)
Geode	GPFS	1.2	0.6	NA
Data Capacitor II / DC-WAN	Lustre	6.47	4.85	NA
Scholarly Data Archive	HPSS	1.8	1.5	18
Totals		**9.47**	**6.95**	**18**

Table F. 3. Summary of data storage resources available at Indiana University

4.1. Backup and replication within IU Storage Systems

The backup and/or data replication procedures for IU storage systems are as follows:

- *The Research File System.* RFS is backed up nightly to the SDA and saves versions for at least the previous seven days, seven weeks, and two months. While users must request a restore of one of these versions, the previous day's version of each of the user's files is immediately accessible in the one-day backup directory in that user's account.
- *The IU Data Capacitor II and DC-WAN.* Data stored on the Data Capacitor II and DC-WAN are not backed up automatically. This system was designed primarily for short-term data storage. However,

data from the Data Capacitor can easily be transferred to the SDA from any of IU's compute resources, so replica copies may easily be maintained.

- *IU's Scholarly Data Archive (SDA)*. By default, data stored within the IU Scholarly Data Archive are stored in duplicate copies – one in the tape silo at IU Bloomington, and one in the tape silo at IUPUI in Indianapolis. User data is not backed up to other external systems. The HPSS metadata specifying which tapes contain any given file is backed up continuously; multiple copies exist in Indianapolis and Bloomington.

As noted in Section 7, the system security and its documentation are in compliance with NIST 800 Security Standards.

4.2. Facilities for handling sensitive data

IU has put in place appropriate administrative, technical, and physical controls to protect data in accordance with the HIPAA security rule. Electronic Personal Health Information may be stored on all of the HPC and storage facilities described in this document.

4.3. Services lists and disaster recovery planning

IU has a written disaster recovery plan for every service and system it provides, which is by definition an experimental facility. (See a full list of services at: https://webdb.iu.edu/uitsfs/scripts/abc/reports/web_files/0910/RCQS/Basic/RCQS_09-10_UA_BASIC.pdf) IU also has a contract in place for use of an off-site disaster recovery facility in case of a disaster affecting one or more of IU's campuses. If a disaster strikes one core campus (IUPUI or IU Bloomington), the disaster recovery plans call for restoring service at whichever core campus remains operational. Plans are also in place for service recovery if a disaster strikes both core campuses simultaneously.

5. Networking

The basic logical structure of IU data networks can be subdivided into three primary components: connections between high-speed research networks and commodity Internet to IU, the IU research network, and the IU enterprise network. These network connections and major features of the IU cyberinfrastructure are shown in Section 7 (see page 44). The IU research network meets ESNet's definition of a Science DMZ and, by placing research systems outside the general campus network, has operated as such since 2004.

The primary connection between IU and national research networks is a 100 Gbps network link from Internet2 to the Indiana GigaPOP in Indianapolis. The Indiana GigaPOP is a collaborative facility operated by the IU GlobalNOC on behalf of collaborating partners Ball State University, Indiana University, Purdue University, and the University of Notre Dame. IU was the first site to connect to Internet2 at 100 Gbps as part of the Monon100 project. In the first half 2013, IU's 100 Gbps was extended from Indianapolis to the main campus in Bloomington. IU also has a dedicated 10 Gbps connection to the XSEDE network. In 2013, the Indiana GigaPOP connection to the CIC OmniPOP was upgraded to 100 Gbps. For redundancy, the GigaPOP also maintains four 10 Gbps redundant and physically isolated connections to commodity Internet.

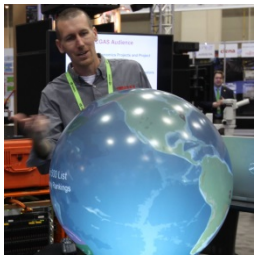
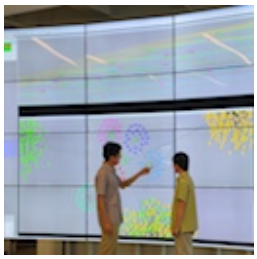
The IU Research Network uses the 100 Gbps connection installed as part of the Monon100 project as its backbone from the Indiana GigaPOP to the IUPUI campus in the Informatics and Communications Technology Complex building, and from there to Bloomington and the IU Bloomington Data Center (both physical facilities described in section 1). Seventy percent of the capacity of these links is dedicated to research use. Within both data centers on the IUPUI and IU Bloomington campuses, Brocade switches function as "machine room backplanes." These switches provide connections among cyberinfrastructure systems within the data centers. Through them, all cyberinfrastructure systems in Indianapolis and Bloomington are interconnected.

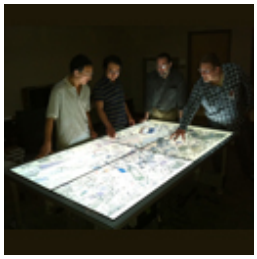
IU maintains a separate enterprise network for business and general academic use. This enterprise network peers with the research network in Indianapolis and Bloomington to provide users with redundant connectivity. The IU research network also has a redundant path to the commodity Internet via the enterprise network, in case connectivity between Indianapolis and Bloomington is interrupted.

6. Advanced visualization facilities

The IU Advanced Visualization Laboratory (AVL) serves as a university-wide resource for visualization, virtual reality, advanced graphics, and visual telecollaboration for researchers, educators, students, and artists in all departments on all campuses. AVL has eight full-time staff and can host graduate students for extended projects. The AVL maintains and operates a number of advanced visualization resources, including but not limited to ultra-high-resolution displays, virtual reality environments, 3D cameras, scanners, spatial input systems, and haptic feedback devices.

-  *The Virtual Reality Theater* is a bright, high-resolution, immersive virtual reality technology resource suitable for individual and group use. The Theater is reconfigurable and driven by workstation computers running either Windows or Linux.
-  *The Visualization & Collaboration Theater*, a three-screen, front-projected display, offers either stereoscopic or monoscopic high-definition visualization and presentation capabilities for up to 60 people.
-  *Science on a Sphere (SOS)* is a spherical display developed by NOAA that blends four high-resolution projectors to create a seamless image on a globe nearly 6' in diameter. IU's SOS is located in the atrium of the Cyberinfrastructure Building (CIB) on the Bloomington campus, and can be used to display a variety of scientific and information visualizations as well as digital art and other interactive experiences.

-  *Puffersphere* is IU's newest spherical display. It features a smaller footprint than SOS – which allows it to more easily move between buildings or campuses – as well as a multi-touch interface to facilitate new forms of collaboration and interactive exploration.
-  *The Ultra-High Resolution Display Wall* consists of eight high-resolution projection cubes totaling 15.3 million pixels. The Display Wall is capable of receiving input from multiple sources simultaneously, making it ideal for teleconferencing, group collaborations, and/or multiple highly advanced visualization applications. Like the IQ-Wall described below, it is driven by a single computer.
-  *The IQ-Wall* is an AVL design that ties thin, energy-efficient, flat-screen monitors into configurations that meet the requirements of the users and the space. These walls are driven by a single Windows computer. The premier unit is located in the lobby of the Cyberinfrastructure Building (CIB) at IU Bloomington.
-  *The IQ-Table* is a 55" monitor equipped with 32-point multi-touch capabilities, which make it ideal for lobbies, libraries, or off-site exhibits. Its built-in computer and shipping case make it easy to ship, set up, and tear down.

-  *The IQ-Tilt* features four monitors tiled together in a 2x2 configuration. This nearly 100" display is treated as one Windows desktop driven by a single computer, and is multi-touch enabled. Its name comes from the fact that this display pivots on an axis, and can be reconfigured in fewer than 10 minutes into either a horizontal table or a vertical wall.
-  *The IQ-Force* features a tabletop device that combines stereographic rendering with physical force and tactile feedback. When users can see their own hands in the same physical vicinity as the virtual simulation, they experience a more natural sense of scale, orientation, and augmentation.
-  *The IQ-Station* is a low-cost stereoscopic display with optional user interface components including touchscreens and/or input device tracking. A fully equipped Station is most suitable for scientific research groups; simplified versions are excellent for stereoscopic screening and production, and for conferences and outreach events.
- 

Head Mounted Displays are available through AVL, along with comprehensive software workflows for creating and deploying virtual reality experiences. AVL's primary HMD is the Oculus Rift, but other mobile VR platforms are available. AVL offers training and assistance as well as limited licensing opportunities for the Unity Engine. This combination of Rift hardware and Unity software lowers the barrier of entry to creating immersive experiences.

-  *3D Scanning and Digital Object Preparation* are areas in which AVL staff have knowledge and workflows broadly related to object and environment scanning. AVL owns and operates multiple 3D scanners, which can be used in AVL facilities or loaned out. To complement the scanning process and preparation for digital fabrication (i.e., 3D printing), AVL staff are also well versed in converting and manipulating all types of digital 3D models.
-  *Advanced Media Capture Equipment* maintained by AVL includes a high-end, professional stereoscopic camera rig capable of filming authentic productions. Video captured with this rig can be edited using software available to all IU students, faculty, and staff. AVL's Gigapan robot can be used to automatically capture multiple 2D photographs of a scene or environment. Once the individual photos have been composited together, users can interact with the final panoramic image via web browsers. AVL also has THETA cameras capable of capturing 360-degree images and videos with a single click. These images and videos look great in an immersive, head-mounted display.

7. Federal systems security policy and federal funding agency policy compliance

The IU high-performance computing and storage systems described here are managed and administered in ways that meet National Institute of Standards and Technology (NIST) 800 security standards. OVPIT and UITS comply with the NIH Grants Policy Statement.

8. Central information technology organizations

The Indiana University Office of the Vice President for Information Technology (OVPIT) and University Information Technology Services (UITS) are responsible for delivery of core information technology and cyberinfrastructure services and support. OVPIT and UITS collectively have an annual budget of more than $110,000,000 and employ more than 700 full-time staff members. The Pervasive Technology Institute (PTI) – a collaborative effort of OVPIT, UITS, the IU School of Informatics, and the Maurer School of Law – is IU's flagship resource for information technology research, development, and delivery.

9. Appendix 2: EOT activities

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
7/1/2014	Galaxy Deployment on Heterogeneous Hardware	Galaxy Community Conference 2014/ Baltimore MD	Talk on Galaxy using Mason Quarry BR2 and OSG	150
7/3/2014	LaPlaza VR Racing Workshop (SOIC) Organized	IUPUI - Advanced Visualization Lab	Guests were taught how To build a 3D race course and test it in VR.	11
7/7/2014	Accelerate Your Science: Introduction to High Performance Computing	IUB - Innovation Center	Accelerate Your Science: Introduction to High Performance Computing	30
7/11/2014	AVL tour for Purdue MEAP summer Camp	Minority Engineering Advancement Program / IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	16
7/11/2014	AVL tour for Purdue MEAP summer Camp July 2nd and July 11th	Minority Engineering Advancement Program / IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	20
7/11/2014	Lego Robots activity	Minority Engineering Advancement Program / IUPUI - School of Engineering and Technology	Helped students building Lego robots	21
7/13/2014	NEON Advanced Analysis of Genomic Data in Microbial Ecology Research Workshop	NEON / Boulder, CO	a working group to direct the use of NEON microbial data	25
7/14/2014	AVL tour for SOIC Seeing Sideways class Monday July 14th	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	11
7/14/2014	Campus Bridging Technologies using the Basic XSEDE Cluster Stack	Extreme Science and Engineering Discovery Environment (XSEDE14) / Atlanta, GA	Campus Bridging Technologies using the Basic XSEDE Cluster Stack	30
7/15/2014	TextRWeb: Large-Scale Text Analytics with R on the Web	Extreme Science and Engineering Discovery Environment (XSEDE14) / Atlanta, GA	Wernert was listed as a speaker	28
7/15/2014	BOF: Empowering Campus Champions and Campus Bridging Engineers	Extreme Science and Engineering Discovery Environment (XSEDE14) / Atlanta, GA	Henschel, Thota, Knepper, and S. Michael presented.	34
7/16/2014	SOIC Summer Workshops AVL Tour Series	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff each tour.	102
7/16/2014	Using Galaxy	IU Bioinformatics Clinic 2014 / IUB	Teaching the basics of Galaxy with intermediate concepts and examples	4

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
7/17/2014	Tutorial: SciGaP Tutorial: Developing Science Gateways using Apache Airavata	Extreme Science and Engineering Discovery Environment (XSEDE14) / Atlanta, GA	Pierce, Marru presented.	10
7/17/2014	BOF: Running Scientific Workflows on XSEDE	Extreme Science and Engineering Discovery Environment (XSEDE14) / Atlanta, GA	Pierce, Marru presented.	22
7/18/2014	#125257: tour for Cummins	IUB Technology Park	#125257: tour for Cummins	6
7/21/2014	No Guts, No Glory and Supercomputing	Minority Engineering Advancement Program / IUPUI - School of Engineering and Technology	Taught students about parallel computing (supercomputing) and how to put together and boot up a computer (No Guts, No Glory).	24
7/21/2014	The Case for an Open and Evolving Software Assurance Framework	2014 International Conference on Software Engineering Research and Practice (SERP)	Overview of software assurance challenges and the SWAMP	N/A
7/22/2014	#124863: Cathy Allison (from MST) visit to AVL	IUB and IUPUI - Advanced Visualization Lab	#124863: Cathy Allison (from MST) visit to AVL	1
7/22/2014	AVL tour for OneNet GRNOC guests	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	5
7/22/2014	Genomics in July Workshops	Genomics in July / IUB - Cyberinfrastructure Building	Workshop on Bioinformatics for Biologists	12
7/24/2014	An Open Continuous Assurance Facility	OWASP Indianapolis	Overview of software assurance challenges and the SWAMP	N/A
7/25/2014	"Cassava genomics: can genomic technology benefit smallholder farmers in Africa?"	Genomics in July / IUB - Cyberinfrastructure Building	Talk from Dow /AZ State Steve Rounsley	18
7/29/2014	Clark State REU Intro to UNIX and HPC Tutorial	Clark State - Fairfield, OH	Introductory talk on UNIX and high performance computing	15
8/1/2014	#125060: EOT: Tour for Delegation of Chinese educators (Purdue Guests)	IUPUI - Informatics & Communications Technology Complex	Tour for Delegation of Chinese educators (Purdue Guests)	6
8/4/2014	#125925: NIDA University in Thailand	IUPUI - Informatics & Communications Technology Complex	Informatics tour for Visiting Delegation from Thailand	3
8/5/2014	#126071: EOT: Lillian Stokes and Guest tour	IUPUI - Informatics & Communications Technology Complex	#126071: EOT: Lillian Stokes and Guest tour	2

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
8/5/2014	Monitoring HPC Clusters	Linux Clusters Institute Workshop on High Performance Cluster Computing / NCSA, University of Illinois Urbana-Champaign	Tools techniques & issues related to monitoring HPC clusters	100
8/6/2014	Advanced Topics: Cluster Business Models	Linux Clusters Institute Workshop on High Performance Cluster Computing / NCSA, University of Illinois Urbana-Champaign	Panel discussion compare contrast models for allocating HPC resources	100
8/12/2014	Media Arts and Science Summer Bridge group AVL tour Aug. 12th	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	27
8/19/2014	UITS RT Services table/booth	IUPUI New Faculty Orientation / IUPUI - Campus Center	Table promoting UITS RT services	38
8/20/2014	SOIC Dean Guest Tour	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	2
8/20/2014	UITS Research Technologies services booth/table	Graduate Student Orientation Fair / IUB	Table promoting UITS RT services	32
8/21/2014	Outreach to the Kelley School of Business	IUB - Kelley School of Business Hall of Honor	Provided information about RT services at IU to faculty and grad students.	25
8/22/2014	#127523: New University College Advisors Tour	IUPUI - Informatics & Communications Technology Complex	#127523: New University College Advisors Tour	6
8/22/2014	UITS Research Technologies Cyberinfrastructure for IU Research and Academics	Electrical and Computer Engineering Graduate Student Orientation / IUPUI	Presentation by Dave Hancock and table/booth by Robert Ping	32
8/26/2014	HPC HIPAA and FISMA: Meeting the Regulatory Challenge through Effective Risk Management	2014 NSF Cybersecurity Summit / Washington D.C.	Barnett/Shankar co-presented a tutorial on regulatory issues	20
8/26/2014	Developing Cybersecurity Programs for NSF Projects	2014 NSF Cybersecurity Summit / Washington D.C.	Sons & Jackson were part of a group presenting on how to develop comprehensive cybersecurity programs for NSF funded projects	27
8/27/2014	Cybersecurity for NSF Science: What does that mean?	2014 NSF Cybersecurity Summit / Washington D.C.	Presentation regarding how cybersecurity translates to NSF projects	117
8/28/2014	SOIC Parkland College Guests AVL Tour	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	2

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
9/4/2014	PTI Seminar: 60 minutes with the National Science Foundation (Anita Nikolich)	IUB - Cyberinfrastructure Building IQ-Wall	An overview of the NSF Advanced Cyberinfrastructure Division (ACI) which supports scientists and engineers who use advanced computation data-handling and networking to make discoveries.	42
9/4/2014	Security Seminar Series: Fostering Innovation in Cybersecurity (Anita Nikolich)	IUB – Maurer School of Law Moot Court Room	Seminar reviewing the strategic direction of NSF's Cybersecurity Programs and a review of currently funded awards and present opportunities for future funding.	N/A
9/9/2014	Identity Management for Virtual Organizations	32nd EUGridPMA Meeting	Overview of XSIM activities	N/A
9/12/2014	IndianaMap FOSS4G conference award	FOSS4G 2014 / Portland, OR	FOSS4G is the largest global gathering focused on open source GIS	300
9/15/2014	vis session at RTD2014	Research & Technology Development 2014 / Missouri University of Science and Technology	vis session at RTD2014	150
9/16/2014	eXtreme Scale Identity Management for Scientific Collaborations (XSIM)	2014 NGNS PI Meeting	Overview of identity management for virtual organizations	N/A
9/17/2014	UITS Research Technologies Cyberinfrastructure for IU Research and Academics	Digital Library Brown Bag Series / IUB - Herman B Wells Library	Presentation about UITS RT services.	22
9/18/2014	NACAC AVL Tours and Evening IUPUI Event	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demonstration led by AVL staff.	200
9/18/2014	Light and Fiber Optics Activities to engage students in STEM	Makerspace at Crane NWSC	Hands-on learning about properties of light and how fiber optics transmit data	16
9/18/2014	Security Seminar Series: Internet Voting Both Sides of the Story (Dr. Alec Yasinsac)	IUB – Maurer School of Law	Seminar covering internet voting and present approaches for addressing the security challenges it faces	N/A
9/22/2014	AVL tour for N500 Informatics Graduate Students	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demonstration led by AVL staff.	22
9/23/2014	Intro to HPC @ IU	IUB	Intro to HPC	19

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
9/23/2014	Introductory Parallel Programming for Supercomputers Workshop	IUPUI - Informatics & Communications Technology Complex	Parallel Programming Workshop	18
9/24/2014	AVL Tour for CEO-NET International	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demonstration led by AVL staff.	17
9/25/2014	Software Assurance Marketplace (SWAMP): An Open Continuous Assurance Facility.	Regenstrief Developer University	Overview of the SWAMP	N/A
9/26/2014	IUPUI JagDays Tour for K-12 Guests	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demonstration led by AVL staff.	22
9/29/2014	Intro to HPC @ IU	IUPUI	Intro to HPC	6
9/30/2014	Cybersecurity for Cyberinfrastructure and Science!	2014 HUBub	Overview of cybersecurity for science	N/A
10/2/2014	Security Seminar Series: Meatball Surgery: Operational Information Security at al Large Higher Education Institution (Andrew Korty)	IUB – Maurer School of Law	Seminar covering the practice of operational information security at an R1 institution	N/A
10/3/2014	AVL Tour for Circle City Classic Overnight Visit	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demonstration led by AVL staff.	3
10/3/2014	UITS RT Services Table	Kelley School of Business IT Open House - IUB	Provided information about RT services using all in one monitor and business school application.	18
10/4/2014	Engaging K-12 in Science Technology Engineering and Math (STEM) activities	Celebrate Science Indiana / Indiana State Fairgrounds - Indianapolis, IN	Ready Set Robots! Wavelength and Make a Speaker activities	162
10/6/2014	Getting Started: Research File System at IU	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	20
10/6/2014	Overview: Scholarly Data Archive best practices	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	20
10/6/2014	Getting Started: Data Capacitor 2	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	30
10/6/2014	IUScholarWorks and data management plans	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	15
10/6/2014	Overview: SHAARP	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	15
10/6/2014	Introduction to research computational and database systems	Statewide IT Conference 2014 Making it Click / IUB	Presentation by RT	15

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
10/6/2014	Overview: Storage, collaboration, and file sharing at IU	Statewide IT Conference 2014 Making it Click / IUB	Panel on file storage and sharing options for the IU community	62
10/6/2014	How to Stay Ahead of the Digital Criminals, Avoid a Data	TechPoint / Indianapolis, IN	Panel as part of TechPoint's New Economy New Rules Cybersecurity: The New Normal	N/A
10/7/2014	AVL Tour for Pike High School International Baccalaureate students and chaperons	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	40
10/7/2014	National Center for Genome Analysis Support	Statewide IT Conference	Introduction to NCGAS and its services available to all IU community	4
10/7/2014	3d printing at IU	Statewide IT Conference / IUB	talk on 3d printing at IU	50
10/7/2014	The IU Cyberinfrastructure Gateway	Statewide IT Conference / IUB	Presentation by RT	20
10/7/2014	Impostor Syndrome	Statewide IT Conference / IUB	Panel Discusion	N/A
10/8/2014	Pervasive Technology Institute: 15 years and counting	Statewide IT Conference / IUB	Presentation by Craig Stewart and Beth Plale	35
10/10/2014	AVL Tour for Upward Bound High School Guests	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	17
10/14/2014	AVL Tour for Beech Grove High School Students	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	21
10/14/2014	AVL tour for IUPUI University College Undecided Student Tour	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	1
10/15/2014	AVL tour for Emmerich Manual High School (IPS) freshmen students	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	33
10/15/2014	Bi-annual workshop/student program and networking workshop	Pacific Rim Applications and Grid Middleware Assembly Workshop (PRAGMA) / IUB Cyberinfrastructure Building	Robert Ping organized this bi-annual meeting with D2I Center's Plale	78
10/15/2014	Do You Need to Know Your Users?	2014 Fall HEPiX Meeting / Lincoln, Nebraska	Overview of XSIM research	N/A

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
10/16/2014	QuakeSim E-DECIDER and UITS Research Support	IUB - Student Building Room 331	Presentation to Anthropological Center for Training and Research on Global Environmental Change	10
10/16/2014	Security Seminar Series: All Your SSL Are Belong to Us (Vitaly Shmatikov)	IUB – Lindley Hall Abyss	Seminar covering SSL/TLS	N/A
10/17/2014	AVL Tour for IUPUI Fall Fest Attendees	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	12
10/20/2014	AVL Tour for Rolls Royce Guests	IUPUI - Advanced Visualization Lab	A discussion and demonstration led by AVL staff.	4
10/22/2014	Cyber Threats	Cyber Resilience: A Cybersecurity Summit / Lilly Conference Center / Indianapolis	Panel discussing cyber threats facing small to medium-sized businesses and individuals	N/A
10/22/2014	Cyber Solutions	Cyber Resilience: A Cybersecurity Summit / Lilly Conference Center / Indianapolis	Panel discussing prevention of cyber attacks	N/A
10/23/2014	AVL tour for prospective student (A retired UITS employee's nephew)	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	5
10/27/2014	Pervasive Technology Institute IT Services/Highlights table/booth	Internet2 / Indianapolis, IN	Booth highlighting the services and highlights of RT on IQ table.	25
10/28/2014	Campus Identities for Research	Internet2 Technology Exchange 2014	Presentation regarding identity and science	N/A
10/30/2014	Identity Management for Virtual Organizations: A Model.	Internet2 Technology Exchange 2014	Presentation regarding virtual organizations becoming essential for scientific computing and over view of a model describing VO IdM	N/A
10/30/2014	Burning Issues	HPSS Users Forum / Munich Germany	Forum to review HPSS community's new burning issues and review of previous year's burning issues resolution status.	100
10/31/2014	IU Site Report	HPSS Users Forum / Munich Germany	IU Site Report describing IU's HPSS configuration	100
11/3/2014	Introductory Parallel Programming for Supercomputers Workshop	IUB - Herman B Wells Library	Workshop	14

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
11/3/2014	Data Visualization Hackathon	NSF Polar Cyberinfrastructure Datavis Hackathon / New York NY	Justin Peters and David Reagan participated - centered on polar cyberinfrastructure.	25
11/7/2014	AVL Tour for IUPUI Fall Fest Attendees	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	7
11/7/2014	Introductory Parallel Programming for Supercomputers Workshop	IUB - Herman B Wells Library	Workshop	16
11/8/2014	Girls Inc. Girl Scouts Joint Program AVL Demonstration Activities (VR World Building)	IUPUI - Advanced Visualization Lab	A discussion and activity led by AVL staff.	68
11/11/2014	AVL Tour for SOIC Recruiting guests	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	23
11/13/2014	#130810: EOT: Tour for Informatics Visitor	IUPUI - Informatics & Communications Technology Complex	#130810: EOT: Tour for Informatics Visitor	4
11/14/2014	Low energy/extreme environments computing? at SC14	The International Conference for High Performance Computing Networking Storage and Analysis (SC14) / New Orleans LA	Rich Knepper presented on high performance in field situations where energy sources are unreliable and environments are extreme	20
11/14/2014	Campus Bridging at SC14	The International Conference for High Performance Computing Networking Storage and Analysis (SC14) / New Orleans LA	Rich Knepper presented on XSEDE Campus Bridging Initiatives talking about software to move analyses from the lab to national cyberinfrastructure	25
11/14/2014	Polar Cyberinfrastructure at SC14	The International Conference for High Performance Computing Networking Storage and Analysis (SC14) / New Orleans LA	Rich Knepper presented on IU's field engineering for Polar Science activities	20
11/14/2014	Lustre for Beginners	The International Conference for High Performance Computing Networking Storage and Analysis (SC14) / New Orleans LA	Brief Tutorial on Lustre for the OpenSFS booth	10
11/17/2014	Tour for JagDay Informatics Guests	IUPUI - Advanced Visualization Lab	An informal discussion and demonstration led by AVL staff.	26
11/17/2014	Bioinformatics and cyberinfrastructure support for biologists	The International Conference for High Performance Computing Networking Storage and Analysis / New Orleans LA	NCGAS offers insight into its features and functionality	1300

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
11/17/2014	SC14 station: Science On a Sphere	The International Conference for High Performance Computing, Networking, Storage and Analysis / New Orleans, LA	SC14 station: Science On a Sphere	400
11/17/2014	SC14 station: Immersive tools to support interactive data-intensive visualization	The International Conference for High Performance Computing, Networking, Storage and Analysis / New Orleans, LA	SC14 station: Immersive tools to support interactive data-intensive vi	400
11/17/2014	Data Capacitor II	DDN User Group Meeting	Presentation of Data Capacitor II	100
11/18/2014	Cybersecurity for Science	The International Conference for High Performance Computing, Networking, Storage and Analysis / New Orleans, LA	SC14 Booth Presentation: Cybersecurity for Science	N/A
11/18/2014	Informatics Recruiting K-12 tour 80-120 High School students	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL and Informatics staff.	86
11/18/2014	National Center for Genome Analysis Support	The International Conference for High Performance Computing, Networking, Storage and Analysis / New Orleans, LA	This demonstration will show NCGAS in production	1300
11/18/2014	HPC Systems Engineering Suffering and Administration BoF	The International Conference for High Performance Computing Networking Storage and Analysis / New Orleans, LA	HPC Systems Engineering Suffering and Administration BoF	100
11/19/2014	GIS Day at IU 2014	GIS Day at IU 2014 / IUB	Annual event focused on geospatial technologies	500
11/21/2014	AVL Tour for Cardinal Ritter High School Students	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	16
11/21/2014	AVL Tour for MURI Project Engineering Students doing a VR Project	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	4
11/25/2014	AVL Tour for Kelley Business Student Kevin Chon	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	1
11/25/2014	AVL Tour for Nathanael Tavares	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	1
12/2/2014	Defense and the Rise of New Technologies	Meadowood Retirement Community / Bloomington, IN	Great Decisions Presentation	N/A
12/3/2014	AVL Tour for Steven Voida's HCC undergraduate class	IUPUI - Advanced Visualization Lab	A discussion and demonstration led by AVL staff.	6
12/3/2014	Identity Management for Virtual Organizations	CERN / Geneva, Switzerland	White Area Lectures series with CERN cybersecurity and IT staff	N/A

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12/4/2014	Presentation on Jetstream and Wrangler	NSF Workshop on High Performance Distributed Computing and Polar Sciences / Rutgers University New Brunswick NJ	Justin Miller from Indiana University's (IU) HPC group presented a new NSF cloud system JetStream and NSF data science infrastructure called Wrangler	30
12/4/2014	Security Seminar Series: Cyber Threat Information Sharing (Kim Milford)	IUB - Maurer School of Law	Seminar reviewing the history of information sharing, successful case studies, the role of Federal and state agencies, and challenges to information sharing	N/A
12/5/2014	HCC Brown Bag Seminar Presented by Chauncey Frend Dec. 5th	HCC Brown Bag	A discussion and demonstration led by AVL staff.	7
12/5/2014	Kick-off Meeting	CRIG Summit / IUB - Cyberinfrastructure Building IQ-Wall	Summit for IUSM and IU Health Clinical Research Informatics Group	18
12/5/2014	Advanced Topics in R	IUB - Social Science Research Commons	A talk by Hui Zhang, Scott Michael, and Jefferson Davis the Workshop in Methods series.	19
12/11/2014	#132005: EOT: Acheson Tech 104	IUPUI - Informatics & Communications Technology Complex	#132005: EOT: Acheson Tech 104	7
12/15/2014	Additional AVL tours for TECH104 Students	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL and Purdue MET staff.	42
12/16/2014	Tour for Kelby Dolan	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	3
1/7/2015	Scalar Tutorial	Scholars Commons Workshop Series	Introduction to Scalar and its use in digital publishing.	25
1/21/2015	Tour for N444 Stereoscopic Production course students	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff and SOIC instructor.	6
1/22/2015	Security Seminar Series: CACR Director's Update	IUB – Maurer School of Law	Seminar discussing CACR's activities and accomplishments, future plans, and opportunities for collaboration	N/A
1/23/2015	Wikipedia Edit-a-thon Expanding Diversity	Wikipedia Edit-a-thon Expanding Diversity / IUB Herman B Wells Library	A day long event teaching and encouraging new editors to contribute.	25
1/23/2015	Grammar of Graphics Reading Group	IUB - Woodburn 200 Conference Room	A reading group of staff and students to look at L. Wilkinson's grammar of graphics and an implementation in R.	7

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
1/24/2015	Research Technologies Data Storage for HPC	Big Red II Workshop / IUPUI ICTC Building	Workshop to give users a chance to learn about how to use Big Red II and associated resources	10
1/26/2015	Vis talk by Dr. Oyewole Oyekoya from Virginia Tech	IUB - Cyberinfrastructure Building	visualization talk from visiting AVL candidate	13
1/26/2015	XSEDE workflow support introduction and orientation	Web-based presentation	Online presentation to the XSEDE community about workflow support	89
1/28/2015	Cyberinfrastructure Begins at Home - Prepared for SPXXL	SPXXL Winter Workshop / Wailea HI	HPS SciApt and Research Storage staff presented an update of IU cyberinfrastructure activities	30
1/30/2015	Ray Burke Tour	IUPUI - Visualization and Collaboration Theater	VR tour for Ray Burke and guest	2
2/2/2015	Facilities tour for IUPUI Enrollment Services staff	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	9
2/4/2015	OnBase: Aaron Neal	PTI/RT Seminar / IUB Cyberinfrastructure Building	Aaron Neal presented OnBase (IU institutional repository)	46
2/5/2015	Security Seminar Series: Reasoning Cryptographically About Knowledge (Rafael Pass)	IUB – Maurer School of Law	Seminar cryptographic notions of knowledge	N/A
2/17/2015	Supercomputing for Everyone Series: Faster Work Safer Storage (an introduction)	IUB	This course introduces faculty staff and students to HPC	21
2/17/2015	Open Gateway Computing Environments Science Gateways Platform as a Service	NSF SI2 PI Meeting / Arlington VA	Poster at required PI meeting for all SI2 award recipients.	100
2/18/2015	Supercomputing for Everyone Series: Faster Work Safer Storage (an introduction)	IUPUI	This course introduces IU faculty staff and students to HPC	8
2/19/2015	Security Seminar Series: Insuring Cyber Risks (Christopher French)	IUB – Maurer School of Law	Seminar discussing the various types of cyber risks and the costs and liabilities associated with them	N/A
2/20/2015	TOUR for HCC Faculty Candidates	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	2
2/20/2015	IT @ IU for Humanists	Catapult Lecture Series	Introduction to IT suitable for humanists.	15
2/21/2015	OSS for Research	SCALE (Southern California Linux Expo)	Susan Sons led this presentation	N/A

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2/24/2015	Identity Management for Virtual Organizations: A Model	OWASP – Bloomington Chapter	Presentation regarding virtual organizations and a model that has been developed describing VO IdM based on IdM data production and consumption	N/A
3/2/2015	AVL Tour for I101 Intro to Informatics Class	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff and SOIC instructor.	37
3/3/2015	Software Carpentry Workshop - OSG Connect and DHTC	Software Carpentry Workshop / IUPUI - Informatics & Communications Technology Complex	Introduction to high throughput computing.	11
3/4/2015	IRB and RT: Julie Wernert	PTI/RT Seminar / IUB Cyberinfrastructure Building	Julie Wernert on Institutional Review Board guidelines and procedures	28
3/5/2015	Introduction to the Scholars' Commons IQ-Wall	IUB - Herman B Wells Library Scholars' Commons	A workshop demonstrating the IQ-Wall	14
3/5/2015	Security Seminar Series: Hidden GEMS: Automated Discovery of Access Control Vulnerabilities in Graphical User Interfaces	IUB – Maurer School of Law	Seminar discussing graphical user interfaces	N/A
3/6/2015	AVL toys to occupy participants time	2015 IUPUI Jagathon / IUPUI	Overnight dance party to raise money for Riley	750
3/6/2015	UITS Research Technologies Cyberinfrastructure for IU	Instructional Systems Technology (IST) Conference / IUB - School of Education	Presentation (Vis/Sci-apt/Analytics/Grants) & RT Services table/booth	15
3/7/2015	Art + Feminism Edit-a-thon	Art + Feminism Edit-a-thon / IUB - Herman B Wells Scholars' Commons IQ-Wall	Enabling new contributors to art pages on women.	20
3/10/2015	Bonnie Layton Class Visit	IUB - Cyberinfrastructure Building	AVL facilities tour for Bonnie Layton's journalism class.	11
3/11/2015	Jiang Yu Zheng CSCI435 & CSCI590 Class Demo Tour	IUPUI - Informatics & Communications Technology Complex Rooms IT414 and IT403	Jiang Yu Zheng CSCI435 & CSCI590 Class Demo Tour	43
3/12/2015	Decision Day SOIC & AVL Tour	IUPUI - Advanced Visualization Lab	Decision Day SOIC & AVL Tour	6
3/13/2015	Visit from students and Partners in Education (School of Ed)	IUB	Visit from students and Partners in Education (School of Ed) #134711	23
3/16/2015	Open Community Software Development for Science Gateways	Invited Seminar / Notre Dame University	Invited presentation on workflows science gateways and XSEDE	25
3/18/2015	Cybersecurity for Science	Advancing Research Computing on Campuses: Best Practices Workshop	Presentation regarding cybersecurity for science and the CTSC	N/A

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3/25/2015	Resources for Secure Science: XSIM and CTSC	2015 OSG All Hands Meeting	Presentation covering updates from XSIM and CTSC	N/A
3/26/2015	Presented information about IU research services provided by RT.	Cox Research Days / IUB - Hutton Honors College	Met parents and interviewees (undergraduate students)	12
3/27/2015	Wikipedia Edit-a-thon Expanding Diversity: In Memory of Adrianne Wadewitz	Wikipedia Edit-a-thon Expanding Diversity / Herman B Wells Library IQ-Wall	Teaching and enabling new contributors.	30
3/30/2015	Presented information about IU research services provided by RT.	Cox Research Days / IUB - Hutton Honors College	Met parents and interviewees (undergraduate students)	15
3/31/2015	HCC TT Candidate AVL Tour	IUPUI - Informatics & Communications Technology Complex AVL	HCC TT Candidate AVL Tour	1
4/1/2015	Linear Fascicle Evaluation for Big Data: Multi-thread, memory efficient factorization approach to study individual variability in large human populations: Franco Pestilli	PTI/RT Seminar Series / IUB - Cyberinfrastructure Building IQ-Wall	Franco Pestilli presented his research and how RT services enabled it.	45
4/1/2015	Privacy in the Digital Age	Great Decisions / Columbus, IN	Presentation on privacy for group members	N/A
4/2/2015	Studying Word Usage in Shakespeare with the Help of R	Shakespeare Association of America / Vancouver, Canada	presented tutorial	20
4/2/2015	Security Seminar Series: Provable Privacy in the Wild: Challenges and Open Questions	IUB – Maurer School of Law	Seminar discussing the disconnect between theory and practice of privacy technologies	N/A
4/6/2015	Impromptu Tour of the SOS and CIB IQ-Wall	IUB - Cyberinfrastructure Building Science on a Sphere, IQ-Wall	Impromptu tour of the SOS and IQ-Wall for two visitors. (#136120)	2
4/7/2015	Z637 Class Visit	IUB - Cyberinfrastructure Building Science on a Sphere, IQ-Wall	Tour of SOS and IQ-Wall for Z637 Class	18
4/7/2015	Jetstream Lightning Talk	GlobusWorld 2015 / Argonne National Laboratory	Presentation on Jetstream capabilities and purpose	94
4/8/2015	Supercomputing for Everyone: Intro to Parallel Programming Workshop	IUPUI - Informatics & Communications Technology Complex	Sci-Apt staff presented this class to IU faculty, staff and students	4
4/9/2015	AVL Tour for N450 "Usability" Informatics Class	IUPUI - Advanced Visualization Lab	An informal discussion and demo led by AVL staff.	26

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
4/9/2015	Supercomputing for Everyone: Intro to Parallel Programming Workshop	IUB - Herman B Wells Library	Sci-Apt staff presented this class to IU faculty, staff and students	10
4/11/2015	College of Arts and Sciences STARS Research Symposium	IUB - Cyberinfrastructure Building IQ-Wall	Hosting the STARS symposium on the IQ-Wall in the CIB.	85
4/13/2015	Choose Lustre	Lustre User Group Meeting 2015 / Denver CO	Stephen Simms presented a Introduction to the Lustre Parallel File System	180
4/13/2015	GSS Shared Key Update and Using UID Mapping in Lustre 2.7	Lustre User Group Meeting 2015 / Denver CO	Stephen Simms gave a description and status report of contract work IU is doing for OpenSFS	180
4/15/2015	Geography class tour of SOS and IQ-Wall (#132566)	IUB - Cyberinfrastructure Building Science on a Sphere, IQ-Wall	Tour and overview of the SOS and IQ-Wall for a geography class.	14
4/15/2015	Tour for School of Science guests	IUPUI - Informatics & Communications Technology Complex AVL	School of Science guests	3
4/15/2015	Scalability Testing of DNE2 in Lustre 2.7	Lustre User Group Meeting 2015 / Denver CO	Stephen Simms gave a report on metadata research performed on Lustre version 2.7	180
4/15/2015	Jetstream: A science & engineering cloud	56th HPC User Forum / Norfolk VA	Jetstream project outreach to inform the HPC community at large	107
4/15/2015	Trustworthy Computational Science: A Multi-decade Perspective	Internet2 Global Summit	Presentation reviewing cybersecurity and science	N/A
4/16/2015	Chris Peebles Memorial Lecture Series	Chris Peebles Memorial Lecture Series / IUB - Herman B Wells Library Scholars' Commons	Invited guest speaker, Felix Bachmann of Carnegie Mellon Software Engineering Institute, presented.	62
4/16/2015	Research Services Expo	Research Services Expo / IUB - Herman B Wells Library	UITS, iSGTW, IU Libraries, ORA, D2I, and Research Technologies explained research services to IU faculty, staff, and students.	105
4/16/2015	Peebles Lecture and Research Services Expo (CI Days)	IUB - Herman B Wells Library	Presented science gateway group information at the expo.	5
4/17/2015	UITS Research Technologies Cyberinfrastructure for IU	IUPUI Research Day / IUPUI Campus Center	Booth highlighting the services and highlights of Research Technologies.	24
4/17/2015	UITS Research Technologies Cyberinfrastructure for IU	IUPUI Office for Women and IU Women in Technology Tech Talk / IUPUI Campus Center	Presentation by Robert Ping and Tassie Gniady.	6

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4/20/2015	Cluster Installation at Marshall University	Marshall University Huntington, WV	Installed XCBC at Marshall University	6
4/22/2015	Passport to Science	The Project School - Bloomington, IN	Exploratory science night for kids and caregivers	100
4/23/2015	#136862: EOT: Fang CS Class Tours	IUPUI - Informatics & Communications Technology Complex AVL	#136862: EOT: Fang CS class tours	30
4/24/2015	The Grammar of Graphics: An Introduction to ggplot2	IUB - Social Science Research Commons	An introduction the ggplot2 library in the Workshop in Methods series of talks	21
4/24/2015	Cryptoparty: Penguicon Edition	Penguicon / Southfield, MI	Workshop on everyday cryptography implementations	N/A
4/25/2015	DHS Industrial Control Systems Cybersecurity 301	Penguicon / Southfield, MI	Training session covering securing ICS and SCADA systems	N/A
4/26/2015	Real Life Science: Get Techie	Wonderlab Museum Bloomington, IN	NCGAS presented a DNA assembly puzzle to young people	50
4/27/2015	CEWIT SOS Tour	IUB - Cyberinfrastructure Building Science on a Sphere	IUB SOS Tour	20
4/28/2015	Z637 Information Visualization Final	IUB - Cyberinfrastructure Building IQ-Wall	Final presentations for Z637 Information Visualization	26
4/28/2015	InCommon Goes International: What Interfederation Could Mean to You	Internet2 Global Summit	Presentation regarding the status of the work done by the InCommon Federation and the implications of the federation's work	N/A
5/1/2015	Cybersecurity Leadership	Tobias Leadership Conference	Panel featuring David Delaney and Bill Barnett	N/A
5/4/2015	AVL Tours for TECH104 Morning Class	IUPUI - Informatics & Communications Technology Complex AVL	An informal discussion and demo led by class Professor and AVL staff.	32
5/5/2015	Facilitating Scientific Collaborations by Delegating Identity Management: Reducing Barriers and Roadmap for Incremental Implementation	PNNL	Presentation to scientific and IT professionals on the XSIM research and follow up discussions	N/A
5/7/2015	Facilitating Scientific Collaborations by Delegating Identity Management: Reducing Barriers and Roadmap for Incremental Implementation	NLCIO Meeting	Presentation to the DoE Laboratory CIO meeting on the research results from the XSIM project	N/A
5/11/2015	XSEDE / ACI-REF Meeting	Clemson, SC	Met with Clemson and ACI-REF staff to discuss merging efforts	15

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5/12/2015	The NIST SP 800-63 LoA Revision Process	34th EUGridPMA Meeting / Copenhagen	Discussion of the status of the Level of Assurance (LoA) around the updates to NIST SP 800-63	N/A
5/16/2015	Analysis of Authentication Events and Graphs Using Python	SIAM Workshop on Network Science / Snowbird, UT	Poster Session	N/A
5/18/2015	CIC Directors tour of SOS IQ-Table and IQ-Wall (#137741)	IUB - Cyberinfrastructure Building	Tour and overview of the SOS IQ-Table and IQ-Wall for the CIC Directors group.	10
5/18/2015	Jetstream Overview - EGI 2015	European Grid Infrastructure / Lisbon Portugal	Vas Vasiliadis presented a talk on Jetstream.	30
5/19/2015	Geography class tour of SOS and IQ-Wall (#137740)	IUB - Cyberinfrastructure Building	Tour and overview of the SOS and IQ-Wall for a geography class.	9
5/20/2015	Keynote: Perceptions and Barriers to Resilience	5th Annual Secure and Resilient Cyber Architectures Invitational, MITRE	Keynote Presentation	N/A
5/20/2015	Resource Managers and Job Schedulers	Linux Cluster Institute/Oklahoma City OK	System admin staff gave an overview of the TORQUE resource manager and Moab job scheduler	40
5/20/2015	Advanced Job Scheduling	Linux Cluster Institute/Oklahoma City OK	System admins presented advanced job scheduling policies	40
5/21/2015	AVL tour for N485 Augmented Reality class	N485 Augmented Reality Informatics Class / IUPUI	An informal discussion and demo lead by class Professor and AVL staff.	11
5/22/2015	Outreach activity	2015 KY EPSCoR Annual Conference / Lexington KY	Craig Stewart was invited plenary lunch speaker	180
5/23/2015	High school Outreach	IUB - Cyberinfrastructure Building	Tour of the cyberinfrastructure building	23
5/27/2015	EarthCube All Hands Meeting	EarthCube All Hands Meeting / Arlington VA	Present XSEDE to EarthCube community	15
6/1/2015	Big Data on Ice	ICCS 2015 International Conference On Computational Science / Reykjavik Iceland	Rich Knepper presented a paper detailing Operation IceBridge efforts in the polar sciences	10
6/2/2015-6/3/2015	Toward Evidence-Based Information Security Practice: The DOE Science Community's Opportunity for Real World Information Security Operations Research	DOE ASCR Cybersecurity for Scientific Computing Integrity Workshop	Craig Jackson presented a white paper	N/A
6/3/2015	UITS RT/PTI Seminar: HIPAA and Cyberinfrastructure Task Force	IUB - Cyberinfrastructure Building IQ-Wall	Anurag Shankar and Craig Stewart presented.	41

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
6/3/2015	A Tale of Two Universities: Tools for Managing Research Services - Indiana University & iLab	AAMC GIR IT in Academic Medicine Conference / San Diego CA	A panel discussion comparing tools for research core facility management for IU (iLab) and Univ of Iowa (SPARC).	200
6/4/2015	Ready Set Robots! Camp Session 1	IUB - Cyberinfrastructure Building IQ-Wall	Computer programming workshop for grades 6-12 using Lego Mindstorms.	20
6/5/2015	Ready Set Robots! Grand Challenge session 1	IUB - Cyberinfrastructure Building IQ-Wall	Campers from Ready Set Robots! show off their programming to friends and family.	51
6/5/2015	Ready Set Robots! Camp Tour of the Data Center	IUB - Data Center	Jenett Tillotson led a tour of high performance facilities for friends, family, and campers of the robot camp.	24
6/5/2015	Secure Document Sharing in the Cloud: Indiana University	2015 Information Technology in Academic Medicine Conference	Presentation and joint panel with U. Michigan and Stanford U. on using Box for ePHI sharing	20
6/5/2015	Closing Plenary Session: The Information C-Suite Shares Strategies	2015 Information Technology in Academic Medicine Conference	Panel presentation from Academic Health Center Informatics Leaders	150
6/8/2015	Mini University - Prague and the Czech Republic: A Cultural Exploration	Mini University / IUB - Indiana Memorial Union	Robert Ping hosted a session presented by Craig Cravens of College of Arts and Sciences.	102
6/10/2015	AVL Tour for Nanotechnology Summer Camp	Purdue Nanotechnology Summer Camp / IUPUI	An informal tour and discussion and demo lead by AVL staff.	26
6/10/2015	Supercomputing for Kids	Bloomington High School South Tech Class / Bloomington IN	Presented overview of supercomputers to class training to support laptop operations for all 1800 BHSS students	16
6/10/2015	Mini University - Tour of the Musical Arts Center	Mini University / IUB	Robert Ping hosted a session presented by Tridib Pal of the Musical Arts Center staff.	22
6/11/2015	BioHealth Informatics team tour and discussions for Eskenazi Professionals	IUPUI - ICTC Advanced Visualization Lab	An informal tour and discussion and demo lead by AVL staff.	11
6/15/2015	Facilitating Scientific Collaborations by Delegating Identity Management	Second Workshop on the Changing Landscape in HPC Security	Presentation by Von Welch, Bob Cowles and Craig Jackson	N/A

Date	Education, Outreach, and Training Event Title	Conference Name/Location	Description	Total Attendees
6/16/2015	Jetstream: A Distributed Cloud Infrastructure for Under-resourced higher education communities	The Science of Cyberinfrastructure: Research Experience Applications and Models (SCREAM-15) / Portland OR	Jeremy Fischer gave the presentation.	25
6/16/2015	Authentication and Authorization Considerations for a Multi-tenant Service	The Science of Cyberinfrastructure: Research Experience Applications and Models (SCREAM-15) / Portland OR	Presentation by Randy Heiland	N/A
6/17/2015	Solving Identity Management Problems with SeCs	TNC15 / Porto, Portugal	Presentation on the topic of an extension of the results from the XSIM research project	N/A
6/22/2015	Informatics Tour Gaming Summer Camp	IUPUI - ICTC Advanced Visualization Lab	Informatics Tour Gaming Summer Camp	37
6/25/2015	Ready Set Robots! Camp Session 2	IUB - Cyberinfrastructure Building IQ-Wall	Computer programming workshop for grades 6-12 using Lego Mindstorms.	22
6/26/2015	Ready Set Robots! Grand Challenge session 2	IUB - Cyberinfrastructure Building IQ-Wall	Campers from Ready Set Robots! show off their programming to friends and family.	54
6/26/2015	Ready Set Robots! Camp Tour of the Data Center	IUB - Data Center	Kurt Seiffert led a tour of high performance facilities for friends, family, and campers of the robot camp.	6
			Total attendees:	**11,595**